INITIAL REMEDIAL INVESTIGATION

Big River Mine Tailings Sites
Old Lead Belt
St. Francois County, Missouri

April 1995

DRAFT

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Prepared By

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Prepared For

The Doe Run Company

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EXECUTIVE SUMMARY

From 1972 to 1995, many agencies and institutions investigated the potential health effects and environmental impact of the mining sites in the Old Lead Belt of St. Francois County, Missouri. The data from these investigations has been compiled, reviewed, and evaluated in this initial RI report. The purpose of this effort was to: 1) determine if the mine tailings have been adequately described, both physically and chemically, 2) select constituents of potential concern (COPCs), 3) identify data needs, 4) determine if the risks to human health and the environment can be calculated from the existing data, and 5) determine if near-term, interim actions are needed to stabilize the tailings and minimize erosion.

The Big River Mine Tailings Sites

As part of this initial RI, the collected data was evaluated to meet the stated objectives. A history of the Old Lead Belt was developed using historical maps, photographs, documents, and interviews with knowledgeable individuals. Based on this effort, the following nine Big River Mine Tailings Sites (BRMTS) sites were identified:

- Desloge
- Leadwood
- Bonne Terre
- Doe Run
- National
- Elvins/Rivermines
- Federal
- Hayden Creek
- Big River Sediments

This initial RI provides a complete operational and regulatory history of the BRMTS.

Overview of the Old Lead Belt

The history of the Old Lead Belt is well documented, and information has been summarized back to the 1700s. Historical maps, photographs, and documents were consulted to determine the locations of mining operations, tailings, and smelters for each site. The tailings have been sampled repeatedly over the past 14 years, the metal content of the tailings is well understood. The selection of lead, cadmium, and zinc as COPCs is therefore well founded. Furthermore, any action taken to contain the lead, cadmium, and zinc would also address and contain the lesser contributions of the other, trace metals in the tailings. Some information on Doe Run and Hayden Creek will need to be supplemented with field sampling and data analysis to determine the residual concentrations of metals in the soils.

Site Data

Based on the data from previous investigations, of this RI provides an overview of available data by environmental media.

Soils. Data on metals in the site soil has been collected through several investigations indicating elevated levels of the COPCs. This data will be supplemented by the field sampling program to be conducted this year by The Doe Run Company and by the blood lead and environmental sampling to be performed by the Missouri Department of Health (MDOH).

Surface Water. COPCs have been documented in the sediments of the Big River and to a lesser extent in its surface water, but not above any applicable or relevant and appropriate requirements (ARARs). The results of the surface water analyses will be used in the baseline human health risk assessment to determine the extent of risk from COPCs in the water.

Drinking Water and Groundwater. The MDOH will sample the drinking water of 300 homes in the Old Lead Belt this summer. COPC concentrations measured to date have been primarily below drinking water standards. A 1994 report by the Agency for Toxic Substances and Disease Registry (ATSDR) indicates that the levels of lead in drinking water are near a federal action level. One confounding consideration is that lead plumbing appears to be quite common in the area.

Sediments. The sediments within the Big River are well defined with regard to the COPCs. The dredging of sediments to remediate the COPCs would disrupt the sediment component of the ecosystem and may cause the resuspension of the sediments in the water column, moving the COPCs further down river. This initial RI focused on the information needed to protect the tailings from wind and surface water erosion.

Air Quality. Air Quality monitoring in and around Desloge has been completed for total suspended particulate (TSP), and the sampling did not identify TSP above any federal or state air quality standard. When the TSP monitoring was conducted (in the early 1980s), TSP was considered the valid national ambient air quality standard (NAAQS). The TSP standard has since been replaced by the inhalable particulate standard of 10 microns or less, otherwise known as PM-10. Since the inhalation of dust is a key pathway for human and ecological receptors, it is important to obtain PM-10 information. For the purposes of the risk assessment, PM-10 air monitoring will be proposed as part of the 1995 field sampling program.

Analysis of Data

The analysis of data indicates that the metal content of the tailings has been quantified in several characterization efforts. Essentially, the materials are the same from location to location. In this initial RI, a quantitative analysis of the metals tested in tailings was conducted to determine the COPCs, and lead, cadmium, and zinc were selected. Estimates of the volume of tailings are presented and the extent of contamination is discussed. Toxicological assessments of the three COPCs are provided from a variety of sources but primarily the EPA's Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST).

Data Quality Review

An evaluation of the suitability of existing study data to meet the EPA's data quality objectives for CERCLA sites was conducted and the results presented in the RI. A major conclusion of this RI is that the characterization of the tailings is essentially complete. One exception is that specific data is needed to perform the human health risk assessment. For the risk assessment, the top six inches of tailings should be sampled to assess the potential risk due to the COPCs. Other data needs should be addressed using data from this summer's sampling programs. The MDOH program will collect blood-lead data on sensitive residents and environmental samples from soils, drinking water, and in-home dust. This data and field sampling and analysis to be conducted by The Doe Run Company will provide additional information for the focussed RI.

Exposure Scenarios

While elevated concentrations of lead, cadmium, and zinc have been identified, the potential human health risk of these concentrations will be estimated by the baseline human health risk assessment. The risk assessment will be conducted after the MDOH completes its field sampling program this summer and will incorporate its results. The scope will include discussions of the potential users of the sites ("receptors" of COPCs), possible routes of exposure and human intake, and the bioavailability of the three COPCs.

On March 1, 1995, in St. Francois County, The Doe Run Company and its representatives met with staff members from EPA Region VII, the MDOH, Missouri Department of Natural Resources (MDNR), and the U.S. Fish and Wildlife Service (USFWS). At this meeting, it was agreed that an ecological risk screening would be completed in April 1995. The purpose of the screening study is to determine, using conservative parameters, whether further ecological risk assessment is justified. It was also decided at the meeting that the COPCs for ecological risk screening would be lead, cadmium, and zinc. The aquatic and terrestrial biological endpoints to be compared to the no-observed-adverse-effect levels (NOAELs) are described in of this RI.

Conclusions and Recommendations

Based on the review and evaluation of previous Old Lead Belt investigations, data needs have been identified. In response, this summer the MDOH will complete a human-health and environmental sampling and analysis program involving 300 homes in the Old Lead Belt. In addition, The Doe Run Company will initiate field sampling and analyses. The results of these investigations will be summarized and used to supplement this RI. Specifically, the following tasks are proposed:

- Perform additional field sampling and analyses; incorporate results into the RI
- Complete the baseline human health risk assessment; add to the RI
- Complete the ecological risk screening; incorporate results into the RI
- Add lead research and results of on-site blood-lead tests to the RI
- Cut off wind erosion and surface water contact with the tailings
- Perform studies to supplement the knowledge base of pile stabilization
- Complete the baseline human health risk assessment
- Integrate the field sampling results into the RI
- Implement a Graphic Information System

In summary, the tailings currently represent a replenishing source of COPCs to the environment. Throughout St. Francois County, the tailings are essentially the same, containing the same COPCs, differing only in pile size and shape. The BRMTS should therefore be addressed on an area-wide basis, since the same materials--and COPCs--are present at all sites. The release of

COPCs to the environment will decrease with the stabilization of the tailings and as wind and rain erosion are minimized. A series of interim remedial measures (IRMs) should be performed to stabilize the tailings and prevent further erosion.

Upon completion of the IRMs, and this summer's field sampling and analysis, the RI would then use the completed IRMs as the starting point for baseline conditions. However, disturbing either the tailings or Big River sediments to retrieve COPCs may mean using dispersing actions that would entrain the COPCs in the air or water. This could potentially cause greater risk to human health and the environment than would simple stabilization and continued monitoring. Therefore, no additional remedial actions (other than stabilization) are recommended until the baseline human health risk assessment and the ecological risk screening are completed. The results of the MDOH blood-lead study and environmental sampling and analysis will allow the mapping of any areas where higher blood-lead levels are documented. This mapping could then be used to prioritize further activities.

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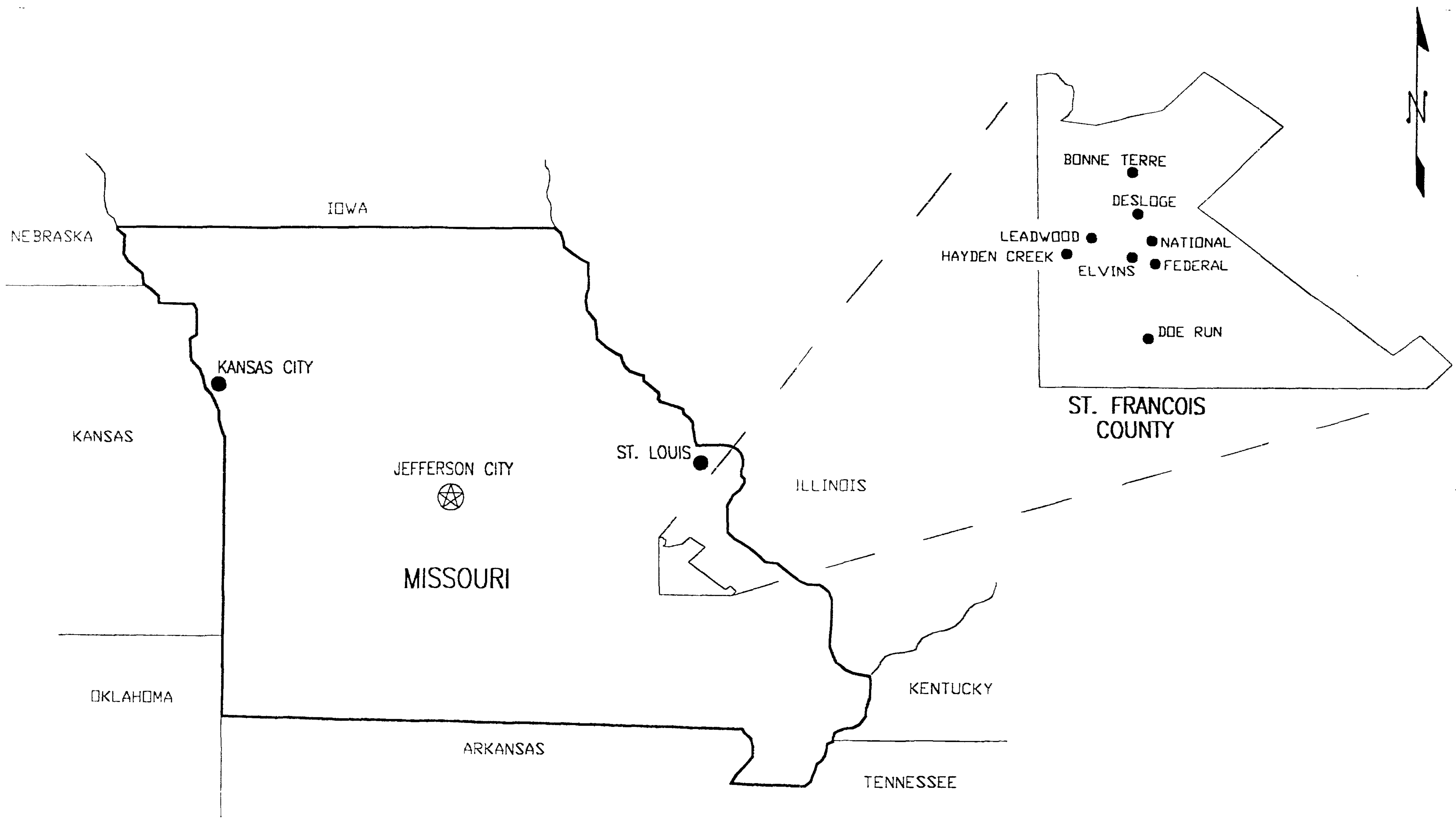
ACRONYMS

ARARs	applicable or relevant and appropriate requirements
ATSDR	Agency for Toxic Substances and Disease Registry
B-TAG	Biological Technical Assistance Group
BRMTS	Big River Mine Tailing Sites
Cd	cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
COPC	constituents of potential concern
CY	cubic yards
DNR	Department of Natural Resources
DQO	Data Quality Objectives
EDF	Environmental Defense Fund
EE/CA	Engineering Evaluation/Cost Analysis
EPA	Environmental Protection Agency (U.S.)
ERT	Environmental response team
FS	feasibility study
FSP	field sampling plan
FWS	Fish and Wildlife Service
HEAST	Health Effects Assessment Summary Tables
HQ	hazard quotient
ILCR	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
LDRs	land disposal restrictions
LOAEL	lowest observable-adverse-effect level
mg/g	milligram per gram
mg/kg	milligram per kilogram
MCL	maximum contaminant level
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
MDOH	Missouri Department of Health
MSMI	Missouri State Mine Inspector
NAAQS	National Ambient Air Quality Standards
NFRI	National Fisheries Research Laboratory
NOAEL	no-observable-adverse-effect level
NPL	National Priorities List
OSWER	Office of Solid Waste and Emergency Response
Pb	lead
pH	measure of acidity/alkalinity
ppb	parts per billion
PM-10	inhalable particulate matter less than 10 microns in diameter
ppm	parts per million
PRPs	potentially responsible party
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RME	reasonable maximum exposure
RTC	Report to Congress
TSP	total suspended particulate
ug/m^3	micrograms per cubic matter

USBM	U.S. Bureau of Mines
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
Zn	zinc



VICINITY MAP
NOT TO SCALE

GENERAL LOCATION MAP
ST. FRANCOIS COUNTY, MISSOURI

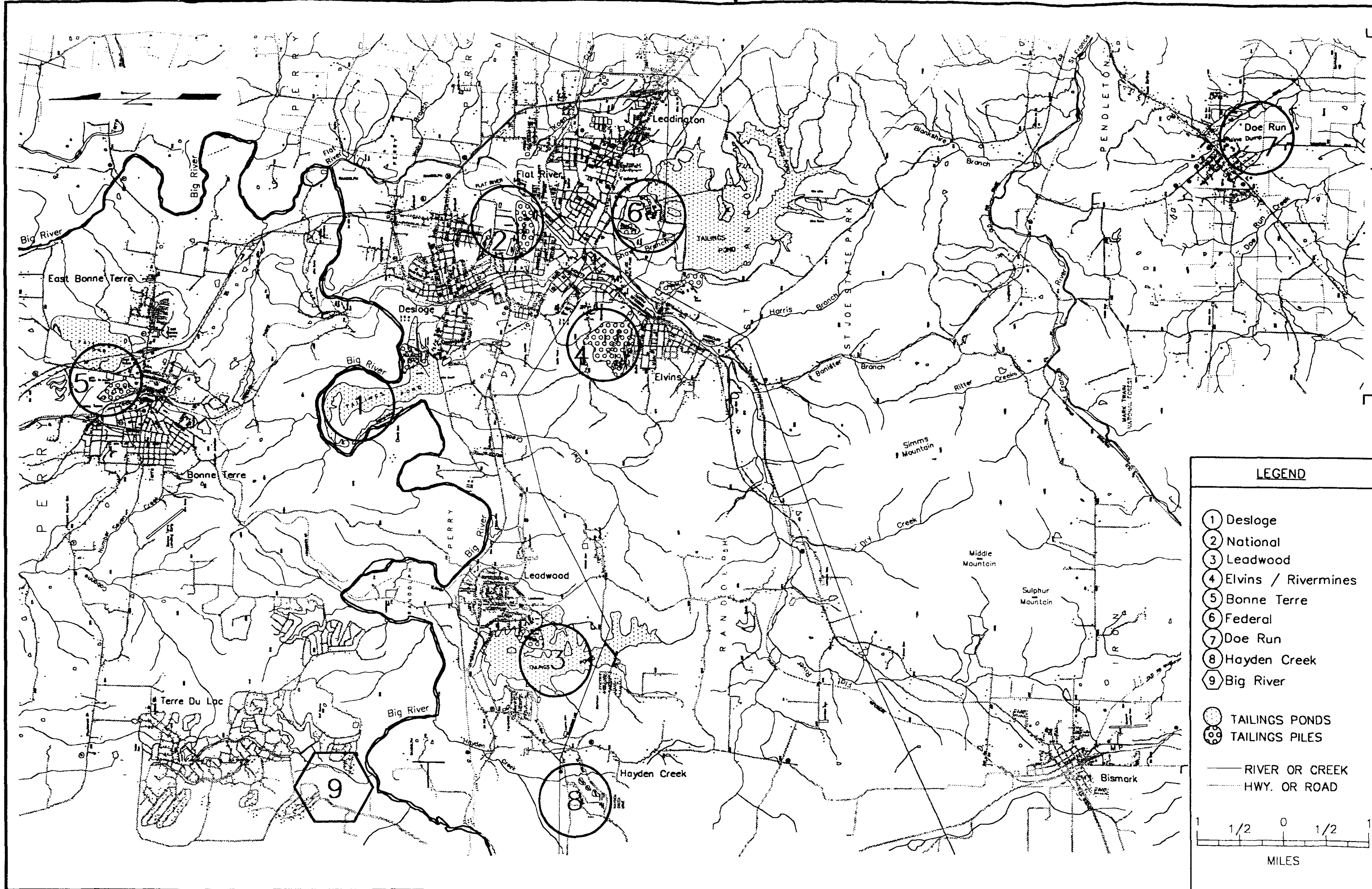
REVISION: 1
REVIEW DATE: APRIL, 1995

THE DOE RUN COMPANY

PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730

CADFILE: DRVICIN.DWG
CONTRACT: 04438907

FIGURE 1-1



BIG RIVER TAILINGS SITES
ST. FRANCOIS COUNTY, MISSOURI

REVIEW DATE: APRIL, 1995

REVISION: 1

THE DOE RUN COMPANY

PLANS PREPARED BY: FLUOR DANIEL
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CADFILE: DRUSGS.DWG

FIGURE 1-2

1.0 INTRODUCTION

The first recorded mining in St. Francois County occurred in the early 1700s. Over the years, the mines, milling operations, and associated facilities in the county became known as Missouri's "Old Lead Belt" (Figure 1-1). Mining operations ceased in this area in the mid 1970s. What remains are remnants of buildings and tailings deposits produced during the mining operations. The tailings contain elevated concentrations of lead, cadmium, and zinc, all of which can impact the environment.

The Doe Run Company has voluntarily undertaken numerous studies in the Old Lead Belt to quantify the potential hazards associated with the tailings. Agencies and other organizations have also undertaken studies.

In conjunction with the U.S. Environmental Protection Agency (EPA), The Doe Run Company has contracted with Fluor Daniel, Inc. to perform an "initial RI/FS [Remedial Investigation/Feasibility Study] with the ultimate intent of developing a comprehensive remedial action approach to the overall Old Lead Belt area."

The approach used in this study divides the Old Lead Belt into eight mining sites plus the sediments of the Big River. Together these nine areas are referred to as the Big River Mine Tailings Sites (BRMTS). The sites are shown in Figure 1-2 and listed below:

- Desloge
- National
- Leadwood
- Elvins/Rivermines
- Bonne Terre
- Federal
- Doe Run
- Hayden Creek
- Big River Sediments

Records show that the Old Lead Belt area in southeast Missouri produced over 8,100,000 tons of pig lead concentrates during the 100-plus years of mining operations. The by-product of the milling process resulted in the production of materials called chat and tailings. An estimated 250 million tons of chat and tailings were generated over this period (Sears, 1985). Table 1-1 provides an estimate of the acres covered by BRMTS chat piles and tailings ponds.

Chat is the fine to coarse dolomite rock fragments produced during the early milling process in which density separation was used to separate the ore. Chat was transported mechanically by conveyor and deposited in large piles at heights generally greater than 100 feet above the surrounding topography.

Tailings were produced by a wet chemical process. Sometimes referred to as fines, tailings typically involve smaller fragment fines, silts, silty sands and clay. The tailings were hydraulically deposited into impoundments known as tailings ponds.

By convention, past documents have used "tailings" as a general term to encompass both chat and tailings (MDOH, 1994). This document uses the term in a similar fashion.

Another term referred to in this document is "poor rock" also known as development rock. Poor rock is the material removed while excavating to gain access to the ore. This rock is generally dumped in piles near the shaft being developed. This rock is the coarsest type generated in the mining process.

TABLE 1-1
CHAT PILE AND TAILINGS POND ACREAGE

Site	Chat Pile Acres	Tailings Pond Acres
National	44	108
Elvins	72	77
Bonne Terre	39	306
Doe Run	9	0
Hayden Creek	0	0
Federal	43	1005
Desloge	95	275
Leadwood	35	528

Source: Sears, 1985

1.1 Objectives of this RI

The BRMTS are similar in nature because of the similarities in their past mining and milling operations which will ultimately lead to similar remedial actions using related engineering solutions. To arrive at these solutions, the following objectives were identified and accomplished as a first step in the RI/FS process.

The consideration of historical data in qualitatively analyzing the potential sources of contamination at the various sites is the foundation of the RI process. This information, along with existing data, is an integral part of developing the conceptual model for the RI. Historical information on the following has been gathered, reviewed, and analyzed:

- Materials produced, stored, or deposited on site
- Descriptions of material handling methods
- Duration of activities
- Quantities of materials handled during operations
- Site permits
- Shutdown procedures
- Identification and locations of mining surface features and facilities
- Chronology of site operations
- Review of aerial photographs

To expedite RI preparation, the information has been presented in a format consistent with the RI report. This format, however, may be refined further.

Review of Environmental Data

The environmental data has been reviewed for its sufficiency to determine or characterize surface and groundwater hydrology, Big River sediment loading and transport, soil contamination, ambient air quality, animal and plant uptake of heavy metals, and the bioavailability of lead, cadmium, and zinc in the tailings. The goal of this effort was to successfully characterize the sites to the extent required for potential future action and to meet regulatory requirements without data duplication. It is possible that further investigations will be required.

The compilation and review of environmental data were used to isolate and rank the importance of:

- Sources
- Constituents of potential concern (COPC)
- Existing human receptors
- Existing animal receptors
- Existing aquatic receptors
- Transport mechanisms
- Existing exposure pathways
- Known toxicity information

Data Review and Quality

The EPA's adopted system of classifying analytical data was used to fit the accuracy and precision requirements of a fit-for-purpose criterion on CERCLA projects. Data was classified into one of five levels depending upon its intended use. The proposed uses of the data are known as data quality objectives (DQOs).

Identification of Data Gaps

Once the available data was sorted, data gaps were identified through an iterative process involving disciplines such as risk assessment, conceptual modeling, contamination delineation, and remediation action engineering. Each discipline reviewed all available data to determine if the data is sufficient, with respect to number and location of samples, data quality, and detection limits, to fit the specific purpose of the discipline. Areas with incomplete data were identified for each discipline, and then all data gaps were examined comprehensively to determine the scope of the field sampling plan.

Preparation of Sampling and Analysis Plans

Once data needs and DQOs were identified, a proposed field Sampling and Analysis Plan (SAP) was prepared to govern the collection of additional data. The SAP consists of three elements: a Quality Assurance Project Plan (QAPP), a Field Sampling Plan (FSP), and a Health and Safety Plan (HASP). Each proposed plan was written in accordance with EPA guidance, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA - Interim Final.*

Conceptual Model Preparation

A human health and ecological conceptual model was prepared which relates the area-wide sources and fate and transport of contaminants to receptor exposure.

1.2 Regulatory History

During a severe storm in 1977, a portion of the tailings pile at the Big River on the southeast edge of the Desloge Site became unstable, and an estimated 50,000 cubic yards of tailings were washed into the Big River. When the Missouri Department of Natural Resources (MDNR) discovered the event, it requested that EPA conduct an extensive investigation of the Big River. EPA conducted a survey in late 1977 and found that, based on comparative aquatic population density, the Big River was degraded by the mine tailings that had entered it (EPA, 1993).

In 1980, the Missouri Department of Conservation (MDC) determined that some fish downstream of the tailings pile contained elevated lead levels. As a result of the findings, the Missouri Department of Health (MDOH) issued a press release cautioning local residents not to eat bottom-feeding fish taken from the 50-mile stretch of the Big River from the city of Leadwood (near the BRMT site) downstream to Washington State Park (EPA, 1993).

By December 1981, St. Joe Minerals Corporation, under a cooperative agreement with the state of Missouri, began taking limited actions on the pile to fill the erosion gaps and stabilize the tailings pile. Some smaller failures have been caused by erosion since the massive 1977 release (EPA, 1993).

In the spring of 1985, the Desloge Tailings Task Force was organized to deal with the existing problems of the Desloge site. Organized by the St. Joe Minerals Corporation, the task force consisted of representatives from St. Joe, the landfill operator, MDNR, MDC, the University of Missouri-Rolla, and local officials. The primary objectives of the task force were to: 1) provide adequate site supervision, 2) ensure proper repair and maintenance of erosion gaps on the site, and 3) develop and implement short and long-term stabilization measures (EPA, 1993).

The landfill operators have capped and seeded several closed landfill cells at the site. In 1986, the operators requested a permit from the state of Missouri to expand operation onto 200 additional acres of the tailings pile. In January 1987, as a result of this proposed expansion, MDNR requested that six monitoring wells be installed around the existing landfill to monitor for the presence of leachate in the tailings. SFCEC installed the wells in 1987, and they have been in operation continuously since then (EPA, 1993).

Table 1-2 presents a chronology of rules and regulations, enacted under the Resource Conservation and Recovery Act (RCRA), relating to mining and mineral processing waste regulations.

TABLE 1-2
CHRONOLOGY OF MINING AND MINERAL PROCESSING
WASTE REGULATIONS UNDER RCRA

Year	Regulation
1976	Congress adds RCRA to Solid Waste Disposal Act, orders EPA to study mining wastes - Sec. 8002(f).
1978	EPA proposes first hazardous waste rules; without doing study, includes some mining and processing wastes.
1980	Congress passes Bevill Amendment, deferring regulation of mining industry wastes as hazardous, pending EPA study and report to Congress - RCRA Sections 3001(b)(3) and 8002(p).
1984	RCRA reauthorized. Simpson Amendment authorizes EPA to modify Subtitle C rules if any special wastes determined to be hazardous - RCRA Section 3004(x).
1985	October: EPA proposes to narrow scope of Bevill Amendment coverage of processing wastes and list six processing wastes as hazardous. December: EPA submits report to Congress on extraction and beneficiation wastes ("RTC I").
1986	June: EPA determines the extraction and beneficiation wastes should not be subject to Subtitle C hazardous waste regulation; will develop Subtitle D non-hazardous waste rules for these wastes. October: EPA withdraws proposed rule and listings on processing wastes.
1987	AMC I: court overturns EPA definition of "solid waste," affirms RCRA jurisdiction limited to wastes.
1988	June: EPA releases Strawman I staff draft mining waste rules. July: EDF I - court upholds EPA Subtitle D, non-hazardous waste determination for extraction and beneficiation wastes. EDF II - court reverses EPA withdrawal of proposed processing waste rules. September: EPA lists six processing wastes as "hazardous."
1989	EPA issues high-volume, low hazard criteria for processing wastes.
1990	January: EPA issues second rule applying volume, hazard criteria to processing wastes, removing most from Bevill Amendment coverage. May: EPA releases Strawman II, revised draft of mining waste rules. July: AMC II - court remands listing of five processing wastes as "Hazardous." December: EPA Deputy Administrator authorizes staff to proceed with development of Strawman II-type mining waste rules.

TABLE 1-2 Continued

Year	Regulation
1991	RCRA up for reauthorization; EPA establishes "Policy Dialogue Committee" (PDC) saying previous 1991 target for proposing mine waste rules no longer applies. PDC meetings begin in April, continue almost monthly to January 1992. September: House Subcommittee on Transportation and Hazardous Materials holds hearings on RCRA and mine waste. Discussions begin in October among states, industry, and environmentalists on mine waste legislation. December: D.C. Circuit court in Shell case remands RCRA mixture and derived-from rules.
1992	PDC meets in January and December, while legislative discussions occur almost weekly through March. House Subcommittee staff draft legislative provisions but mine waste title is removed from bill sent to full committee to avoid possible conflict with House Interior Committee.
1993	PDC charter (as federal advisory committee) expires. EPA staff draft "background" and "technical resource" documents on mining industry practices and mineral sectors. EPA issues interim final mixture and derived-from rules identical to those remanded in Shell case; AMC and others seek judicial review. Legislative efforts on mine waste management focus on possible amendments to 1872 Mining Law. RCRA bills address general Subtitle D issues but not specific mine waste provisions. August: D.C. Circuit court in EEI decision remands RCRA toxicity characteristic (TC) rule as EPA had tried to apply it to mineral processing wastes not covered by the Bevill Amendment.
1994	EPA releases final drafts of technical and background documents; also announces it will propose "Phase Four" land disposal restrictions (LDR) rule in mid-1995 covering LDRs for characteristically hazardous non-Bevill processing wastes, re-visit application of TC rule (EEI decision), and remand of five mineral processing wastes (AMC II decision). No RCRA legislative action on mining wastes. Attention remains focused on 1872 Mining Law. Administration drafts (after discussions with industry and environmental groups) re-mining amendment that is added (over industry objection) to CERCLA reauthorization measure in Senate Superfund Subcommittee. Bill dies; no companion re-mining amendment in House bill. September: D.C. Circuit court in Mobil decision vacates RCRA mixture rule as EPA tried to apply it to mixture of Bevill wastes and non-Bevill, characteristically hazardous wastes.

1.3 Previous Investigations

As previously stated, the overall goal of this initial RI was to identify existing data and information that can be used in the second phase of the RI/FS process. Existing data required to perform an RI was reviewed for both the Old Lead Belt and specific sites. This data was extracted from previous studies performed in the area. The following list identifies the studies reviewed; those containing data for evaluation and consideration are presented in Appendix A and summarized in Section 3.0. The numbers (i.e. 120.2.1R, 120.2.2R, etc.) shown below and in other sections of this document are records management indexing numbers.

120.2.1R	Control of Mine Tailing Discharges to Big River
120.2.2R	Lead Studies on Fish, Mussels and Sediments in Big River of Southeast Missouri
120.2.3R	Preliminary Assessment, Big River Mine Tailings, Desloge, St. Francois County, Missouri
120.2.4R	Continued Studies on Vagrant Lead in Fish, Mussels, and Sediments of the Big River of Southeastern Missouri
120.2.5R	Remedial Measures for Control of Mine Tailings Particulates in the Pine Ford Project Area
120.2.6R	A Study on the Possible Use of Chat and Tailings from the Old Lead Belt of Missouri for Agricultural Limestone
120.2.7R	Geochemical Survey of Waters of Missouri
120.2.8R	Lung Cancer Study Points to Tobacco Smoke as Primary Culprit
120.2.9R	Elemental Composition of Selected Native Plants and Associated Soils from Major Vegetation-Type Areas in Missouri
120.2.10R	The Dynamics of Metals from Past and Present Mining Activities in the Big and Black River Watershed, Southeastern Missouri
120.2.11R	The Special Nature of Lead in Mining and Milling Wastes
120.2.12R	Midvale Community Lead Study, Final Report

120.2.13R	1991 Child Lead Study
120.2 14R	The Butte-Silver Bow Environmental Health Lead Study
120.2.15R	Leadville Heavy Metals Exposure Study
120.2.16R	Water Quality Survey of the Southeast Ozark Mining Area, 1965-1971
120.2.17R	Water Quality of the Southeast Ozark Mining Area of Missouri, 1981
120.2.18R	Water Quality of the Southeast Ozark Mining Area, 1974
120.2.19R	Water Quality of the Southeast Ozark Mining Area, 1975
120.2.20R	Water Quality of the Southeast Ozark Mining Area of Missouri
120.2 22R	Uptake of Lead from Aquatic Sediment by Submersed Macrophytes and Crayfish
120.2.23R	Biochemical Changes in Longear Sunfish, *Lepomis Megalotis*, Associated with Lead, Cadmium and Zinc from Mine Tailings
120.2.24R	Use of Sequential Extraction to Evaluate the Heavy Metals in Mining Wastes
120.2.25R	Bioavailability of Pb and Zn from Mine Tailings as Indicated by Erythrocyte θ-Aminolevulinic Acid Dehydratase (AQLA-D) Activity in Sucker (Pisces: Catostomidate)
120.2.26R	Further Characterization and Use of Tailings and Chat from Missouri's Old Lead Belt as Agricultural Lime
120.2.27R	Lead Contamination of Sycamore and Soil from Lead Mining and Smelting Operations in Eastern Missouri
120.2.28R	Chemistry and Plant Ecology of Zinc-Rich Wastes Dominated by Blue-Green Algae
120.2.29R	Missouri Stream Pollution Survey
120.2.30R	Fish from Missouri's Lead Belt: To Eat or Not to Eat
120.2.31R	Lead in Missouri Streams: Monitoring Pollution from Mining with an Assay for Erythrocyte θ-Aminolevulinic Acid Dehydratase (ALA-D) in Fish Blood

120.2.32R Big River - Big Problem

120.2.33R Water Quality Survey of the Southeast Ozark Mining Area

120.2.34R Use of the Pocketbook Mussel, *Lampsilis Ventricosa*, for Monitoring Heavy Metal Pollution in an Ozark Stream

120.2.35R Continued Evaluation of Lead in Fish and Mussels in the Big River of Southeastern Missouri

120.2.36R Accumulation of Lead in Fish from Missouri Streams Impacted by Lead Mining

120.2.37R Toxic Heavy Metals in Vegetables and Forage Grasses in Missouri's Lead Belt

120.2.38R An Evaluation of the Acute Toxicity of Lead, Zinc, and Cadmium in Missouri Ozark Groundwater

120.2.39R Influence of Tailings from the Old Lead Belt of Missouri on Sediments of the Big River

120.2.40R Lead in Fish from Streams in the Old and New Lead Belts of Missouri

120.2.41R Effects of Metals Leached from Mine Tailings

120.2.42R The Butte-Silver Bow County Environmental Health Lead Study - Report of the 1992 Follow-up Lead Screening

120.2.43R Assessing the Validity of Lead Bioavailability Estimates from Animal Studies

120.2.44R Basis for Proposed Soil Lead Removal Levels

120.2.45R Smuggler Mountain Technical Advisory Committee Executive Summary

120.2.46R Micromineralogy of Mine Wastes in Relation to Lead Bioavailability, Butte, Montana

120.2.47R Bioavailability of Arsenic and Lead in Soils from the Butte, Montana, Mining District

120.2.48R Lead Bioavailability: Dissolution Kinetics Under Simulated Gastric Conditions

120.2.49R The Leadville/Lake County Environmental Health Lead Study

120.2.50R Final Report - Bioavailability Study of Arsenic in Soil Impacted by Smelter Activities Following Oral Administration Using New Zealand White Rabbits

120.2.51R Mineral Resources of the United States

120.2.52R Division of Mine Inspection, Annual Reports

120.2.53R Bulletin of the Geological Society of America

120.2.54R Mining and Metallurgy, Index to Volume 28, 1947

120.2.55R Ore Deposits of the United States

120.2.56R Final Report - Bioavailability of Lead in Mining Waste Soil: A Dosed Feed Study Using Sprague-Dawley Rats

120.2.57R Suggested Removal Action Alterative for Consideration in Controlling Wind Erosion and Bank Stabilization, Big River Mine Tailing Site, Desloge, Missouri

120.2.58R Site Assessment: Big River Mine Tailings Site, Desloge, MO

120.2.59R Engineering Evaluation/Cost Analysis for the Big River Mine Tailings Site, Desloge, Missouri

120.2.60R HRS Documentation Record - Big River Mine Tailings Site

120.2.61R Big River Mine Tailings/St. Joe Minerals Corp., Desloge, Missouri

120.2.62R Site Assessment: Big River Mine Tailings, Desloge, Missouri, Addendum Report

120.2.63R Site Assessment: Big River Mine Tailings, Desloge, Missouri

120.2.64R State Mine Inspector Report

120.2.65R Biennial Report of the State Geologist Transmitted by the Bureau of Geology and Mines

120.2.66R Final Report - Listing Site Inspection, Big River Mine Tailings, Volume II

120.2.67R Final Report - Listing Site Inspection, Big River Mine Tailings, Volume I

120.2.68R Shaft Data

120.2.69R Sinking Practice and Costs at the PIM Shaft, St. Louis Smelting & Refining Works of the National Lead Co., St. Francois, MO

120.2.70R Mining and Metallurgy - St. Joseph Lead Company Enterprise

120.2.71R Bulleting of the Geological Society of America

120.2.72R Mining and Metallurgy - Lead Belt Geology

120.2.73R Doe Run Lead Company Minutes

120.2.74R Mining and Metallurgy - Milling Practices in Southeast Missouri

120.2.75Ra Mining and Metallurgy

120.2.75Rb Ore Deposits of the United States

120.2.76R Bioavailability and Toxicity of Metals Leached from Lead-Mine Tailings to Aquatic Invertebrates

120.2.77R Hydrochemical and Sediment Data for the Old Lead Belt Southeastern Missouri, 1988-1989

120.2.78R Big River Mine Tailings/St. Joe Minerals, Desloge, Missouri

120.2.79R The Soil Chemistry of Hazardous Materials

120.2.80R Source and Pathways of Lead in Humans from the Broken Hill Mining Community - An Alternative Use of Exploration Methods, Vol. 89

120.2.81R Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children

120.2.82R Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities

120.2.83R New Policy on Performance of Risk Assessments During Remedial Investigation/Feasibility Studies (RI/FS) Conducted by Potentially Responsible Parties (PRPs)

120.2.84R Wildlife Exposure Factors Handbook, Volume 1 of 2

120.2.85R Big River Bank Stabilization Project Geotechnical Report, Draft

120.2.86R Jurisdictional Wetland Delineation, St. Joe Mineral Corporation, Tailings Disposal Site, Leadwood, Missouri

120.2R.87 Comments on the Preliminary Public Health Assessment, Big River Mine Tailings/St. Joe Minerals

120.2R.88 Toxicological Profile for Lead, U.S. Dept. of Health and Human Services, Public Health Service

120.2.89R Lead Hazards to Fish Wildlife and Invertebrates: A Synoptic Review

120.2.90R Index of St. Joe Documents in Regard to Environmental Matters Related to Doe Run Corporation

120.2.91R Burrell, J., Riverside Technology, Inc., 1995, Letter to J.Tucker, Fluor Daniel, Subject: Agricultural Soil Tests

120.2.92R Rustige, J., State of Missouri, Dept. of Natural Resources, 1995, Letter to D.Vornmerg Company, Subject: Particulate and Lead Air Monitoring Data.

120.2R.93 Frazer, G.D., U.S. Dept. of the Interior, Fish and Wildlife Service, 1995, Letter to M. Saunders, Fluor Daniel, Subject: Listing of Endangered Species in St. Francis County

120.2R.94 Federal Register 5600, 1991

1.4 Organization of the Initial RI

Section 1.0 presents the objectives of this initial RI, namely, to evaluate and summarize environmental data from past reports which can form the basis of a Phase 2 "focused" RI associated with mining operations in the Old Lead Belt area of St Francois County. The study is based on treating the Old Lead Belt as a single "area-wide" site comprised of several mining and related sites: Desloge, National, Leadwood, Elvins/Rivermines, Bonne Terre, Federal, Doe Run, Hayden Creek, and the Big River Sediments.

To help understand how mining and milling operations and processes can impact the environment, a description of past activities is presented in Section 2.0. This section outlines the operational history and presents a chronology of events and operators at each site, including production statistics. Figures depict the historical operating facilities, including buildings, tankage, railroads, disposal areas, and shafts, for each site. The history associated with each site is also discussed along with the technologies used in the mining operations. Background on the site's geologic history is presented as an introduction to the geology discussion presented in Section 3.0.

Section 3.0, Review of Site Data, presents a summary of the data available for use in the RI/FS. This section is divided into topics consistent with the contents required in an RI/FS. For some of these topics, the data presented would be used as is. In others, data gaps exist which require additional research or sampling. A current description of the sites with figures is included in this section. Other topics presented in this section are: topography, climate, air quality, wastes, geology, soils, sediments, surface water, groundwater, and land use. Data summarized in this section, and extracted from Appendix A, is used in Sections 4.0 and 5.0.

Section 4.0, Analysis of Site Data, discusses the selection of constituents of potential concern (COPCs) and defines the sources and extent on contamination. Transport mechanisms and toxicological assessments for the COPCs are also presented.

Based on the availability and validity of the data, gaps were identified. These data gaps are presented in Section 5.0, Screening for Work Plans. To screen the data, the data quality objectives (DQO), presented in this section, were identified. Based on these DQOs, a Sampling and Analysis Plan was developed to fill the data gaps. The components of this plan are described in this section, including a Field Sampling Plan, a Quality Assurance Project Plan, and a Health and Safety Plan.

Section 6.0 identifies, screens, and develops exposure scenarios appropriate for a site located in the Old Lead Belt. These scenarios will provide a basis for evaluating the current potential exposures that may impact human health and the environment. Additionally, the rationale and approach for the ecological risk screening for terrestrial and aquatic species are presented. The ecological risk screening will evaluate the likelihood that adverse ecological effects may occur as a result of chemical stressors in the Old Lead Belt.

Section 7.0, Conclusions and Recommendations, summarizes the data gaps, identifies the number of sites and extent of contamination, sources of contamination, the selected COPCs and recommends areas for further investigation to fill the data gaps. Potential intermediate remedial measures are also discussed, as is the need for an ecological risk assessment.

Section 8.0 presents references cited in this report.

Appendix A presents the results of the data quality review effort. Those studies containing data that meets the EPA's data quality objectives are described. Appendix B presents the draft Health and Safety Plan, while Appendix C presents the draft Quality Assurance Project Plan.

2.0 OVERVIEW OF THE OLD LEAD BELT

2.1 Early History

The first recorded mining in St. Francois County occurred at "Mine-a-Gebore" where operations were conducted on a small scale between 1742 and 1762. "Mine-a-Layne" was discovered about 1795, "Mine-a-Manteo" on the Big River in 1799, and "Mine-a-La Plate" about the same time. A more complete history of the early years of lead production in Missouri and St. Francois County is presented in Section 2.2.1.

The most important lead discovery in southeastern Missouri was that of the disseminated ore in the Bonne Terre, Flat River, and Leadwood areas. The deposits were discovered on the property of the St. Joseph Lead Company (St. Joe) at Bonne Terre in 1864. The most important step in the development of the disseminated lead deposits of the Old Lead Belt was the introduction of the diamond drill in 1869. Prior to 1869, nearly all of the lead ore obtained in the district was mined from shallow surface workings and occurred chiefly in masses or crystal aggregates in crevices, caves, and caverns in limestone and chiefly above the groundwater level.

An enormous increase in the lead production of St. Francois County is attributable to the extensive development of the bodies of disseminated lead ore in the Bonne Terre formation. The lead ore production of St. Francois County to 1869 is estimated to have totaled approximately 59,500 tons. After 1869, the output increased dramatically, as shown in Table 2-1 (Buckley, 1908).

1700 through 1863

Lead ore is believed to have been discovered in Missouri about 1700, and serious attempts at mining were made as early as 1720. For a century thereafter, the chief production of lead in the territories of what is now the United States was derived from Missouri, more precisely from southeastern Missouri. The history of lead mining in Missouri has been related by Arthur Winslow in his *Report on Lead and Zinc* (1894) for the Missouri Geological Survey. The following is excerpted from his report.

TABLE 2-1

TOTAL TONS OF PIG LEAD EQUIVALENT CONCENTRATES PRODUCED BY EIGHT MINING COMPANIES IN ST. FRANCOIS COUNTY, 1865 - 1960
(units are short tons of lead metal equivalent)

Year	Individual Companies[a]	St. Francois Company[b]	Missouri[c]	Southeast Missouri[d]
1865	0			
1866	130			
1867	196			
1868	261			
1869	324			
1870	859			
1871	1060			
1872	1080			
1873	1295			
1874	1963			
1875	2436			
1876	2051			
1877	4569		9311	
1878	5760		10517	
1879	6003		11158	
1880	7068		7970	
1881	9493		30770	
1882	7689		29015	
1883	8554		21600	
1884	9769		18140	
1885	7587		21265	
1886	11381		22460	
1887	7372		27958	
1888	15927		31252	
1889	18844	19465	27400	
1890	19417	16900	33840	
1891	18331	16538	29760	
1892	16822	23740	32895	
1893	18014	20348	32859	
1894	25198	20156	46300	
1895	34145	34510	53596	
1896	43366	42371	51887	
1897	49431	48931	56542	
1898	49992	51011	54469	
1899	49058	54037	54444	
1900	50958			
1901	72247		67172	
1902	81582		79445	
1903	87966		86579	

TABLE 2-1, CONTINUED

Year	Individual Companies[a]	St. Francois Company[b]	Missouri[c]	Southeast Missouri[d]
1904	75394		92275	
1905	79638		104058	
1096	98616		111075	
1907	110929		135902	
1908	111979		141570	
1909	182673		156246	
1910	158616		157796	
1911	158616		175291	
1912	158616		173528	
1913	158616		172259	
1914	139306		188760	
1915	146258		206231	
1916	150849		228426	
1917	171368		229473	
1918	146464		190292	
1919	154403		160024	
1920	154403		161812	
1921	132850		180085	
1922	166930		178412	176768
1923	119438		169743	167468
1924	190710		189929	187737
1925	189500		211566	208915
1926	194436		207012	203062
1927	184156		198760	196251
1928	184679		195393	194270
1929	195352		198469	197435
1930	181119		199632	198622
1931	144649		160121	158950
1932	108635		117159	116152
1933	88719		84980	83970
1934	92870		90493	89580
1935	94324		97493	96491
1936	103913		110428	108422
1937	149633		157631	153205
1938	110483		122027	118870
1939	141765		156281	153522
1940	157470			
1941	154857		165909	164342
1942	160348		199548	197291

TABLE 2-1, CONTINUED

Year	Individual Companies[a]	St. Francois Company[b]	Missouri[c]	Southeast Missouri[d]
1943	172583		184910	179012
1943	156483		174683	169622
1945	157854		176575	173005
1946	119920		139112	135796
1947	114974		132246	129516
1948	88629		102288	100654
1949	110716		127522	126269
1950	119785		134626	133688
1951	111513		123702	122318
1952	110899		129245	122942
1953	112972		125895	125273
1954	115623		125250	125173
1955	114762		125412	125357
1956	111066		123783	123395
1957	114779		126345	126323
1958	107820		113123	113123
1959	101427		105165	105165
1960	104008		111948	111948

[a] From reports of State Mine Inspector for individual companies, includes St Joe, Doe Run, Central, Desloge, Desloge Consol, Columbia/Commercial Lead Co., Federal, and St Louis Smelting Refining Co.
[b] State Mine Inspector reported total for St. Francois County.
[c] Total reported for Missouri by USGS/USBM.
[d] Total reported for southeast Missouri by USGS/USBM.

The first discovery of lead in Missouri was made by Penicaut, a member of Sueur's party that ascended the Mississippi River in 1700. Penicaut refers to a mine reached by the Meramec River, about 50 leagues west of the Mississippi and west of St. Genevieve. It may be inferred from this description that the locality was likely somewhere in Crawford County. The existence of lead in Missouri attracted attention in France, and in 1712 Louis XIV granted the Crozat patent with special privileges as to the discovery and operation of mines in the territory of Louisiana. Little or nothing was actually done, however, until the 1717 transfer of this patent to the Company of the West (better known as the Mississippi Company). The Company of the West's first lead discovery appears to have been made near the Meramec River, by Sieur de Lochon, in 1719. He found ore, but his attempts to smelt it were failures.

In 1719, Philip Francis Renault was appointed director-general of the mines of the Company of the West, and proceeded to Louisiana with 200 artisans and miners, taking on at St. Domingo 500 slaves for working the mines. With Renault came a mineralogist named M. La Motte. In 1720, Renault established himself near Kaskaskia, Illinois where he sent out exploring parties, one of which discovered the Mine La Motte deposits near Fredericktown in Madison County. Although it may not have been the first discovery, Mine la Motte was undoubtedly the first lead mine to be seriously exploited in Missouri. Old Mine and Mine Renault, both near Potosi, were discovered between 1724 and 1726, and mining soon began at these locations.

Renault was the prime mover in early mining in Missouri. He succeeded in building up a flourishing mining and smelting industry, the product being shipped to France via New Orleans. Renault, who received as early as 1723 grants covering the Mine la Motte and other tracts, remained in Missouri until 1742, when he abandoned his work and returned to France.

From 1742 to 1762 mining was superficially prosecuted by the French at Mine la Motte, Old Mines, and Mine-a-Gerbore, all of which had been discovered in Renault's time. In 1763 the Mine-a-Burton was discovered at Potosi by Francis Burton, and work was begun there at once. Other discoveries were made soon afterward in the same vicinity. During the next 30 years lead mining was prosecuted on a small scale at various places in Missouri, chiefly those mentioned above. Shortly after 1795 some new discoveries were made. The Mines-a-Layne about 16 miles south-southwest of Potosi, was discovered in 1795; the Mine-a-Maneto, or American mines, on the Big River, about 12 miles southeast of Potosi, in 1709; and Mine-a-La Platte, near the southeastern corner of Washington County, also in 1799.

Up to this time the lead ore mined in Missouri was galena, occurring entirely as surface deposits in clay. The early openings were very shallow, seldom more than 10 feet in depth. The ore was cleaned of clay by hand and smelted either on log piles or in a crude construction known as the log furnace.

A noteworthy event in the history of lead mining in Missouri was the arrival, in 1799, of Moses Austin, who had formerly operated the mines at Wytheville, Virginia. Austin obtained a grant of one square league at Potosi; in return, he was to erect a furnace and other works, which he did in the following year. Austin introduced what was called the "ash" furnace, which was designed to supplement the poor lead recoveries obtained in the log furnace. It was impossible to attain a good reaction from ore as coarse as that which was charged into the log furnace, and the loss of lead was largely due to its remaining unreduced in the cinders, or ashes, left in the furnace. Austin crushed these ashes and charged them into the ash furnace, which was a crude reverberatory with a sloping hearth, where they were heated about two hours, extending the reaction left incomplete in the log furnace. In this way an additional extraction of about 15 percent was effected. Austin also erected a shot tower in 1799 and a plant for the manufacture of sheet lead, from which the arsenals of New Orleans and Havana were supplied. Moreover, Austin is given credit for inaugurated mining in the rock of the district having sunk a shift to the depth of 80 feet. Previously, all mining had been done by open pits.

An 1804 report by Austin, *A Summary Description of the Lead Mines in Upper Louisiana*, indicates that Austin first visited Missouri in 1797, when he first knew of the Mine-a-Burton. As noted above, in 1798 Austin had obtained a concession of one square league, including about one-third of the Mine La Motte, on the condition that he erect a smelting furnace and establish a lead manufacture. According to Austin, the mines known in Missouri in 1804 include: Mine-a-Burton, Mine-a-Robuna, Old Mines, Mine Renault, Mine-a-Maneto, Mine-a-la Plate, Mine-a-Joe, Mine-a-Layne, Mine La Mott, and Mine-a-Gerbore. Not all of these mines were being worked. The most productive of these was the Mine-a-Burton, after which the Mine La Mott and Old Mines ranked second and third, respectively. The production of all the other mines together was insignificant.

Austin's description of the occurrence of the lead mineral in Missouri surface deposits is substantially the same as observations of similar deposits mined in more recent times. Austin described two types of mineral gravel and fossil. The gravel mineral, was found immediately under the soil in pieces weighting 1 to 50 pounds. The fossil mineral, was found in clay beds underlying 5 or 6 feet of sand rock. Austin reported that "Under the sand rock, mineral of the first quality was found in a bed of red clay in pieces of 10 to 500 pounds weight." This last mineral, according to Austin, "produced 60 percent of its weight in lead when smelted in a common furnace and 15 percent more when smelted again in a slag furnace." The gravel mineral would not produce more than 60 percent lead when smelted.

Austin gives some additional information as to the early methods of mining and smelting. At the Mine-a-Maneto comparatively low-grade ore was being mined, the mineral occurring in thin flakes in a layer of soft gray limestone. According to Austin, "the ore was pounded and washed, 1000 pounds yielding 300 to 400 pounds of mineral." This is interesting as an early example of ore-dressing practice. At the Mine La Mott, Austin reports that the mineral was found in "regular veins, from two to four feet solid," found within 4 or 5 of the surface with a declination of 45 degrees. By about 1800, five of these veins had been opened and were being worked. They could not be mined deeper than about 25 feet, however, and to that depth only in the dry season.

A chronology of the history of lead mining in the United States with particular emphasis on production activities in southeastern Missouri is presented in Section 2.2.1.

Buckley, in a major report (1908) on early mining in St. Francois County, notes that "Hundreds of shallow mines were worked ... mining having been carried on here as early as 1820." He notes that the so-called Butcher diggings were located on property owned by the Federal Lead Company, the Old Mines on property owned by Union, the Bogy Mines on property owned by Desloge, and the La Grave and Pen diggings on property owned by St. Joe, to name a few. Buckley further notes that "these shallow mines were seldom over fifteen or twenty feet deep, although the crevices containing the red clay and aggregates of galena crystals are known to have persisted, in places, to a depth of sixty feet." Continuing, he notes that "an old shaft sunk by the Central Lead Company, prior to the sinking of the present shafts, followed a lead-bearing, clay filled crevice to a depth of sixty feet, where it opened into a large clay pocket containing massive galena. The crevice, although contracting to about one foot, continued below the clay pocket, keeping a general east and west direction."

From the foregoing, and from information summarized in Section 3.0 one can conclude that mining, milling and, to a lesser extent, smelting occurred at numerous locations within St. Francois County and covered a considerable expanse of time. The locations of identifiable, significant operations are presented in Section 3.0 of this report. The nature of operations at these locations, including the likely nature of early operations at the sites, is presented in Section 2.4.

2.2 Operators and Operations, 1864 through 1970

As noted above, Philip Francis Renault led a party of French miners and slaves up the Mississippi River from New Orleans in 1720 and established himself near Kaskaskia, Illinois. From that point, parties were sent out in search of precious metals. One of these parties, led by M. La Motte discovered the deposits that bear his name in Madison County, Missouri, near Fredericktown. Gradually, other mines were discovered in Washington and St. Francois counties, and mining in southeast Missouri was almost continuous from about 1750 through 1970.

Early mining was entirely for chunk galena found in the residuum, which required no milling. The history of lead mining which led to the opening of the Lead Belt in St. Francois County begins on a 946-acre tract of land located at the present site of Bonne Terre. It was known as La Grave Mines. On May 2, 1864, the St. Joseph Lead Company purchased this tract of land, and mining began in open pits that gradually sloped downward until the operation developed into an underground mine; shafts were later sunk for better access to the ore.

In 1869 the first diamond drill was brought to Bonne Terre. Through its use, large bodies of ore were discovered that assured the development of the area as a great mining district. As many as 15 companies were in production during the early years, from the 1860s to the early 1900s. The St. Joseph Lead Company gradually acquired the holdings of these companies and became the only operator in the district in 1933.

2.2.1 Chronology

The rapid development, exploitation, and eventual amalgamation of operations in the Old Lead Belt of southeastern Missouri is best summarized in the following chronology:

<u>Year</u> <u>Report</u>

1887 The US Geological Society reported: "At Bonne Terre, the Saint Joseph Lead Company is turning out lead at the rate of 13,500 tons a year, while the new Doe Run plant is running at the rate of 3,500 tons a year."

Year	Report
1887	The Missouri State Mine Inspector reported: "St. Joe Lead Mine ... reduction works and principal shaft in section 14, township 37, range 4 east, St. Francois County... The company owns about 27,000 acres of land ... The Doe Run Lead Company -Location of plant, northwest one-fourth of section 16, township 35, range 5 east ... 1 incline and 1 vertical shaft ... The mine is new and has been recently purchased by members of the St. Joseph Lead Company ... Valle's Mine - This productive mine is in St. Francois County."
1890	The US Geological Society reported: "Practically, the make of soft lead is controlled by the operations of three great Missouri lead mining companies, the St. Joe, Doe Run and Mine La Motte ...."
1890	The US Geological Society reported: ... the Desloge Consolidated Lead Company is prospecting a tract of 2,300 acres of magnesium limestone similar to the Bonne Terre formation ... a shaft has been sunk to a depth of 220 feet ...."
1891	The Missouri State Mine Inspector reported: "The mineral recently discovered on Flat River has interested a number of parties ... and shafts are being sunk by the Doe Run Lead company, Central Mining company and Judge W. R. Taylor - the Desloge Consolidated Lead company having already sunk a shaft which is producing ore ... Desloge Consolidated Lead Company - ... This company owns about 2,100 acres of mineral lands lying between Big river and Flat river. One shaft has been sunk ... Doe Run Lead Co. ... The company has recently purchased a large tract of mineral land on Flat River ... upon which two shafts are being sunk ... St. Joseph Lead company ... These mines are located at Bonne Terre ... During the past year 13,817.5 tons of pig lead were produced ... The following three mines were in operation ... Shaft No. 1 ... Mine No. 4 ... Mine No. 5 ...."
1894	The Missouri State Mine Inspector reported: "The Central Lead Company -This company is the owner of 1400 acres, situated in the very heart of this great Flat river basin ... In 1890 the company commenced the sinking of a shaft ... The shaft was completed to a depth of 380 feet in the summer of 1983 and in October the erection of

Year	Report
	hoisting plant and concentrator works was begun ... The Desloge Consolidated Company ... has its mine situated about one mile west of Desloge station on the M.R.&B.T.R.R. ... The land on which this company is now operating was first prospected by the Bogy Lead Mining Co. ... Doe Run Lead Company - The mines of this company are situated at Doe Run ... The principal part of their ore is now coming from Flat river ... The shaft is 10 or 12 miles from Doe Run to which point the ore is taken for concentration ... The Flat River Lead Company - The property of this company embraces 1295 acres of land, all in one body, and is located in the great Flat River district ... The Leadington Lead Company ... is one of the new companies in this section ... The mine is situated on part of what was formerly known as the 'McKee mines' and is about two miles distant (east) from Flat River ... This company was first known as the Farmington Prospecting and Mining Company, but in January 1894 changed its name ... The one shaft on the property is down to a depth of 350 feet ... They also have a mill of 100 tons capacity ... St. Joseph Lead Company ... property is situated in and around Bonne Terre ... Beside the mines immediately around the mill, the company is working two other shafts, known as Nos. 7 and 8 respectively, the first being about one mile southwest of the mill; the other being on what is known as the Crawley tract, situated on Flat River, about one mile east of the railroad station of that name ...."
1898	The Missouri State Mine Inspector reported: "St. Joseph Lead Company ... controlling 16,000 acres of mineral land ... The Doe Run Lead Company - Controls 4,000 acres of mineral lands ... The Desloge Consolidated Lead Company ... in 1892 controlled 2,100 acres of mineral land ... it operates two shafts ... The Central Lead Company ... controls 1,600 acres of mineral lands, operates two shafts ... This company having purchased the property and plant of the Theorodore Lead Co., the following must be added to the property ... 184 acres of mineral lands, one shaft ..."
1899	The Missouri State Mine Inspector reported: " ... The St. Louis Smelting and Refining Company ... has secured possession of the old Taylor mines situated about one mile south of Desloge ... the present company has sunk a new shaft ... The Union Lead Company -... has secured the property and plant of what was formerly known as the

Year	Report
	Donnelly Mining Company, embracing 520 acres of land and a 100 ton plant. This mine is about 2 miles southeast of Flat River Station ... Columbia Lead Company - This is a new company, with a new shaft ... The company owns 920 acres of land adjoining the lands of the Central Lead Company and the St. Louis Smelting and Refining Company. A shaft has been sunk ... this shaft and the mill are located on the tract of land known as the 'Higley Tract'. What is known as the 'Pim Tract' is also owned by the company ... The company ... were completing a 250 ton concentrating plant ... a shaft would be sunk on the 'Derby Tract,' the work to commence about December 1st ...."
1900	The US Geological Society reported: "The Guggenheim Exploration Company was organized to take over the properties of M. Guggenheim's Sons in southeastern Missouri, including the Federal Lead Company, which had purchased the Missouri Smelting Company in St. Louis. The company also operates the mines and mineral lands of Union Lead and Oil Company, including the large area purchased from the Missouri Lead Fields Company."
1900	The US Geological Society reported: "A new development in which H. J. Cantwell is concerned, in the Flat River District, is that of the St. Louis Prospecting Company on a tract immediately adjoining the Columbia."
1900	The Missouri State Mine Inspector reported: "... There were 17 shafts operated ... companies operating this last year were as follows: The Central Lead Co., Flat River; The Columbia Lead Co., Flat River; Desloge Lead Co., Desloge; Doe Run Lead Co., Doe Run; St. Joseph Lead Co., Bonne Terre; The Union Lead Co., Flat River ... The St. Louis Smelting and Refining Co. ... has purchased what is known as the Taylor property, and has erected and equipped a plant ...."
1901	The US Geological Society reported: "In southeast Missouri the principal increase in production, among the older mines, was with the Saint Joseph Lead Company and with the Central Lead Company. The latter company has put a new shaft in operation and has blown in a new furnace. The Desloge Consolidated Lead Company smelts the

Year	Report
	greater part of its concentrates locally, but also ships a considerable part to custom smelters. The Columbus Lead Company and the Catherine Lead Company make no pig lead ...."
1902	The Missouri State Mine Inspector reported: "St. Francois County - During the current year it is expected the Manhattan Lead & Land Company will commence sinking a shaft on its property ... Manhattan Lead & Land Company owns 1,200 acres of land adjoining the lands of St. Louis Smelting & Refining Company and the lands owned by the Columbia Lead Company ... St. Joseph Lead Company ... the following brief description ... Mine No. 1 and mill at Bonne Terre ... Mine No. 3; Mine No. 4; Mine No. 5; Mine No. 6; Mine No. 7; Mine No. 8 or Crawley shaft; Mine No. 10, known as the Gumbo ... Mine No. 11 is on land ... that was owned by William and Thomas Hunt ... In speaking of this mine it is frequently called the 'Hunt Shaft'; Mine No. 12 The Hoffman ... is not yet in operation ... Central Lead Company ... ... there are three mines on the tract ... Shaft No. 1 ... Roger's Shaft ... Theodore Shaft ... Columbia Lead Company ... owns 944 acres of land near Flat River, and joins up with the land of the Central Lead Company. Two mines were operated during the year ... St. Louis Smelting & Refining Company - The 1,200 acres of land owned by this company is located between the two large mining towns of Desloge and Flat River. The old Taylor Mine, extensively worked some years ago, is on the property, the same changing hands in 1897 ... The old Taylor shaft was abandoned and shaft No. 2 commenced in August 1898. Shaft No. 3 ... is located 2,400 feet north northeast of shaft No. 1 ... The plant was completed in July 1901 ... Federal Lead Company ... One shaft was operated during the year ... shaft No. 2 has been sunk ... located 1,000 feet east of Flat River and 1,900 feet west of the mill and shaft No. 1 ... Desloge Consolidated Lead Company ... property owned by this company ... is located between Bonne Terre and Desloge ... Derby Lead Company ... owns 6,000 acres of land, part which adjoins some of the fine mining properties in the Flat River district. The company has sunk two very deep shafts ... The shafts are located three quarters of a mile south of Elvins ... Doe Run lead Company ... owns 4,000 acres of land ... There are three shafts of the property ... These shafts are located near Flat River ... with switches leading to each shaft ... The company was organized nineteen years ago ... [and] optioned at that time a portion of

Year	Report
	its present holding from Mr. Wm. R. Taylor, who had done some mining at Doe Run ... After Doe Run had drilled here for six or eight months ... it purchased the property ... A shaft was sunk, a very extensive mill erected, together with a number of calcine furnaces and a refinery ... the company [also] optioned a large body of land in the ... Flat River district ... The first property drilled ... was owned by King Williams. It then moved to ... the Crawley tract; thence to the Walton tract, on which ... it decided to sink a shaft ... The shaft was started ... a water channel was encountered ... this attempt was abandoned ... another shaft started about 1,000 feet distant ... After a lapse of another year, No. 2 shaft was started ... Following this another year found it sinking shaft No. 3 ... Following this shaft No. 4 was started ... No. 5 shaft sunk in four months ... The Foster Land ... some 500 acres of land ... adjoining the Valle mines ... 170 feet deep [shaft] ... some drifting ... 35,000 to 40,000 pounds of lead has been mined ...."
1902	The US Geological Society reported: "The heavy increase in the production of lead in Missouri is due to the rapid development of the mines of southeastern Missouri, a part of the ores being smelted at local works. During 1902 the St. Joseph Lead Company, the Desloge, Central and Mine La Motte mines made at their own works 41,192 short tons of lead ...."
1903	The US Geological Society reported: "... St. Joe, Doe Run, Desloge, Central and Mine La Motte companies produced 44,545 tons in 1903 as compared with 41,192 tons in 1902 and with 35,132 tons in 1901. In the case of the Desloge company this includes some lead smelted on contract by custom smelters. The St. Joseph Lead Company has been making extensive improvements in its mines and its smelting plant at Herculaneum, and is completing a large new concentrating plant at the Hoffman shaft ...."
1903	The US Geological Society reported: "The Desloge Consolidated Lead Company is also building a new mill which will add materially to its capacity. The Central Lead Company, in the Flat River District, is not expected to make so much lead in 1904 as was produced in 1903. ... The Federal Lead Company, which owns the Derby property,

Year Report

did not produce heavily, nor did the Commercial Lead Company, which has leased the Columbia Lead property, make its normal product."

1903 The Missouri State Mine Inspector reported: "Central Lead Company ... Three mines were operated during the year ... Commercial Lead Company ... since June 13, 1903 has been in charge of the land and plant formerly known as Columbia Lead Company ... mines were then leased to the above named company ... Two shafts ... opened ore bodies which were worked during the year ... The third shaft was started during the year ... The company owns and operates a most complete plant ... Mill has a capacity of 250 tons ... Doe Run lead Company ... owns 4,000 acres of land in section 6, 7, 16, and 17, townships 35 and 36, ranges 4 and 5, St. Francois County ... Three mines were operated during the year ... The mines are located on company lands at Flat River, while its reduction works are located at Doe Run ... Federal lead Company ... mineral land owned by this company is located in St. Francois and Washington counties, the total amounting to 13,500 acres ... The Derby is known as Federal No. 2 ... ore from the Derby mine (distance about two miles) is brought by rail ... At present two mines are in operation ... When the plant at Federal No. 1 is completed its capacity will be about 1,200 tons per day ... St. Louis Smelting and Refining ... Two mines were operated the past year ... The 176 jigs in this plant are divided into four distinct divisions ... St. Joseph Lead Company ... The company operated six mines during the year 1903 ... The company has an immense smelter located at Herculaneum ... where the ores from its own mines and those of the Doe Run Company are smelted ... Hoffman Mine (St. Joseph Lead Company) This is a new mine and mill site still in course of construction ... Desloge Consolidated Lead Company ... Three mines were operated during the year ...."

1904 The Missouri State Mine Inspector reported: "Description of the New Hoffman Mill ... built by the St. Joseph Lead Company during the years 1903-1904, is located at Owl Creek, about 4.5 miles west of Flat River. It has a capacity of about 1200 tons per 24 hours ... Federal Lead Company ... commenced operations in 1900 ... the property, known as the Derby Lead Company is controlled by the Federal people ... one large concentrating plant performed all work required by the three mines in operation."

Year	Report
1904	The US Geological Society reported: "The St. Joseph Lead Company, the largest individual producer of lead in the country, has gained in output by enlarging the Bonne Terre mill, by putting into partial operation a new mill at the Hoffman shaft which will be capable of handling 1,000 short tons of ore per day ... The Doe Run Company has operated to full capacity ... The Desloge Lead Company has sunk a new shaft, and has increased its mill capacity by 50 per cent. The company smelts only a part of its product, selling the remainder. The Central Lead Company produced 3,812 short tons of lead in 1904 ... The Central Lead Company has been sold to the American Smelters Security Company. The National Lead Company now ships the product of its Derby mines to the new smelter at Collinsville, Illinois."
1905	The US Geological Society reported: "... in southeast Missouri ... St. Joseph Lead Company considerably increased its output. The Federal Lead Company which is controlled by the American Smelting and Refining Company, and which owns the Derby and Federal mines in the Flat River district ... acquired the mines, concentrator and smelting plant of the Central Lead Company. This company, when in full operation, has produced 5,500 tons of lead per year."
1906	The US Geological Society reported: "The Central mine was dewatered and ... considerable new ground was added to the property. New shafts were sunk by the Central, St. Joseph, Desloge and National companies, and a modern 1,000 ton mill was erected at the Central mine. The Doe Run Company decided to erect a 1,200-ton mill and the capacity of the new Leadwood smelter of the St. Joseph Company was increased by the addition of ten roasting furnaces."
1909	The Missouri State Mine Inspector reported: "Madison Lead and Land Company, now known as the Phoenix Land Company ... Doe Run Lead Company ... owns and controls 6,548 acres of land in this county ... The mining operations of this company are carried on through seven shafts-Nos. 1 and 4 are at Flat River; Nos. 2 and 3 are at Central, about one fourth mile west of Flat River; Nos. 9 and 11 at Esther, two miles east of Flat River; No 6 at Elvins, one mile south; and no. 8 at Mitchell ... the new 2,000 ton mill at Elvins is worthy of special mention ...."

Year	Report
1910	The US Geological Society reported: "The first new company to begin deep mining in this [southeast Missouri] district in several years is the Potosi Lead Company, which in early 1910, began a shaft near Leadwood."
1911	The Missouri Bureau of Geology reported: "The milling capacity of the Flat River district has greatly increased during the past two years. In 1907, the Federal Lead Company completed the erection of a large concentrating plant having a capacity of 3,000 tons per day. The Doe Run Lead Company remodeled the plant located on the old Columbia Lead Company's property and are now erecting a large plant west of Elvins. This mill will have a capacity of 1,500 tons per day."
1912	The US Geological Society reported: "... the Madison Lead & Land Company leased the Catherine mine and mill to the Federal Lead Co. The St. Louis Smelting & Refining Co. relinquished its lease of the Potosi Lead Co.'s mine near Leadwood and the mine was operated by the owners ...."
1913	The US Geological Society reported: "The St. Joseph Lead Company and the Doe Run Lead Company were merged under the name of the former company. The St. Louis Smelting and Refining Company ... received the crude ore from the Potosi Lead Co.'s mine for treatment. The Federal Lead Company operated the Catherine mine."
1915	The Missouri Bureau of Geology reported: "During the past year the Catherine Mine, located near Fredericktown, has been re-opened by the Federal Lead Company. This mine was formerly operated by the Madison Lead and Land Company. The Doe Run Company are erecting an additional section to their mill No. 3, the mill at Doe Run having been closed down. The magnetic plant of Federal Lead Company which burned in October 1912, will be rebuilt."
1923	The Missouri Bureau of Geology reported: "The Pim tract, upon which there is a large body of ore, is being opened by the St. Louis Smelting & Refining Co."

Year	Report
1923	The Missouri State Mine Inspector reported: "Desloge Consolidated lead Company ... During the past year the company has operated three shafts ... St. Louis Smelting and Refining Company ... The company has a 2,500 ton concentration mill ... During the past year the company operated seven shafts ... During the past year the company sank and put into operation one of the deepest shafts in the history ... Federal Lead Company ... At present this mill is treating 4,800 tons of ore ... The company has twelve shafts including those purchased from the Central Lead Co., for the past year ... On October 23, 1923, the St. Joe Lead Co. purchased the entire holding of the Federal Lead Co. ... St. Joe Lead Company ... This company is divided into four divisions, namely, Bonne Terre Division, Leadwood Division, Rivermines Division and Federal Division ... In the course of 30 days they expect to have the Leadwood, Rivermines and Federal divisions cut together, making all three divisions one vast mine ... During the past year this company operated 25 shafts ... has been carrying on considerable prospecting ... on property optioned in the vicinity of Bonne Terre and Irondale and has one shaft down more than 150 feet on the Eaton tract of land near Irondale ...."
1924	The Missouri State Mine Inspector reported: "St. Louis Smelting and Refining Company ... During the last year this company operated seven shafts ... St. Joe Lead Company ... controls 28,113 acres of land in the mineral belt ... Doe Run Lead Company ... controls 6,998 acres of land ... The company operated five shafts ... Most of the mines are located near Rivermines, Mo. ... Desloge Consolidated Lead Company ... has been operating three shafts; at the present time they are sinking a mill shaft so they can hoist direct into the crushing plant ... The mill has a capacity of 1,600 tons daily."
1925	The Missouri Bureau of Geology reported: "The purchase of the Federal Lead company by the St. Joseph Lead Company resulted in a consolidation that makes the latter company the most important lead producing company in the United States ...."
1929	The Missouri State Mine Inspector reported: "An important change occurred during the year when the St. Joseph Lead Company took over the properties of the Desloge Consolidated Lead Company at Desloge, about the middle of the year."

Year	Report
1931	The Missouri State Mine Inspector reported: "The St. Louis Smelting and Refining Company ... operated its mines in St. Francois County a total of 238 days during the year; the St. Joseph Lead Company operated 222 days; the Doe Run Lead Company 224 days ...."
1947	The US Bureau of Mines reported: "In St. Francois County [St. Joseph Lead Company] continued in 1947 to operate four large groups of mines - the Bonne Terre, Desloge, Federal and Leadwood ... The combined daily capacity of the four mills at the end of 1947 was more than 22,000 tons. Treatment is by table concentration followed by flotation ...."
1950	The US Bureau of Mines reported: " St. Joseph Lead Company ... operated its group of mines and four mills (Bonne Terre, Desloge, Federal and Leadwood) in St. Francois County ... These mills have a combined daily capacity of 26,800 tons. Mineral separation is by gravity methods followed by flotation ... Ore from two other shafts at Doe Run is trucked to the Federal mill."
1955	The US Bureau of Mines reported: " St. Joseph Lead Company ... operated its Bonne Terre, Desloge, Federal and Leadwood mine-mill units, its Doe Run and Hayden Creek mines in St. Francois County (ore milled at the Federal and Leadwood mills) ...."
1956	The US Bureau of Mines reported: "St. Joseph Lead Company operated its Federal, Bonne Terre, Desloge and Leadwood mills in St. Francois County ... Two new 9- by 12-foot rodmills were installed in the Leadwood mill ...."
1957	The US Bureau of Mines reported: "St. Joseph Lead Company operated ... its Federal, Bonne Terre, Desloge and Leadwood mills in St. Francois County."
1958	The US Bureau of Mines reported: "About midyear, the Hayden Creek mine was closed indefinitely and equipment removed."
1958	The US Bureau of Mines reported: "The Desloge mill was shut down on June 16 ...."

Year	Report
1959	The US Bureau of Mines reported: "... St. Joseph Lead Company operated its ... Federal, Bonne Terre, Desloge and Leadwood mills in St. Francois County."
1961	The US Bureau of Mines reported: "Three lead mines were closed in 1961 - Madison mine of National Lead Co. and Bonne Terre and National mines of St. Joseph Lead Company."
1961	The US Bureau of Mines reported: "St. Joseph Lead Company operated ... its Bonne Terre, Leadwood and Federal mills in St. Francois County. The Bonne Terre mill, however, was permanently closed in September ... the Federal mill was converted to all flotation ...."
1961	The US Bureau of Mines reported: "St. Joseph Lead Company mined lead ore and operated its Bonne Terre, Leadwood and Federal mills. The company closed its Bonne Terre mine in August, its Bonne Terre mill in September and its National mine in October."
1963	The US Bureau of Mines reported: "More than two million tons of lead ores was mined at St. Joseph's Federal mine near Flat River. The ore was processed at the company operated Federal and Leadwood mills ...."
1975	The US Bureau of Mines reported: "St. Joe Minerals Corp. donated 8,500 acres of land in St. Francois County to the State of Missouri for use as a state park ... The property ... is in the Flat River area of the Old Lead Belt on which St. Joe discontinued mining in 1970."

2.2.2 Operations and Operators

Operators and years of operation are identified in Table 2-2.

TABLE 2-2
ST. FRANCOIS COUNTY LEAD PRODUCERS
1865 - 1970

Operator	Years of Operation	Comment
Central Lead Co.	1891-1904	
Columbia Lead Co.	1900-1904	
Commercial Lead Co.		Leased and operated Columbia Lead Co. property.
Derby Lead Co.	1902	
Desloge Lead Co.	1877-1886	
Desloge Consol. Lead Co.	1890-1928	
Doe Run Lead Co.	1887-1914	
Federal Lead Co.	1902-1923	
Flat River Lead Co.	1894	Known originally as Farmington Prospecting.
Leadington Lead Co.	1893-1894	
Manhattan Lead Co.		
Potosi Lead Co.		
St. Joseph Lead Co.	1865-1970	
St. Louis Prospecting	1900-	
St. Louis Smelt & Ref	1897-1933	
Theorodore Lead Co.		Purchased by Central Lead Co.
Union Lead Co.	1900	Purchased by Federal Lead Co.

2.2.3 Production Statistics

Mine output from the Old Lead Belt of St. Francois County reached a peak in 1942 when 197,430 tons of lead (metal equivalent of concentrates) were produced. Table 2-3 lists total mine production for St. Francois County by company and years of operation covering the time period 1865 through 1965.

TABLE 2-3
TOTAL TONS OF PIG LEAD EQUIVALENT OF CONCENTRATES PRODUCED
BY 15 MINING COMPANIES IN ST. FRANCOIS COUNTY
1865 - 1965

Company	Year of Operation	Production Tons of Pig Lead
St. Joseph Lead Co.	1865-1965	5,889,529
Desloge Lead Co.	1877-1886	28,916
Doe Run Lead Co.	1887-1914	337,601
Leadington Lead Co.	1893-1894	329
Desloge Consol Lead Co.	1893-1928	400,812
Central Lead Co.	1894-1904	51,404
Flat River Lead Co.	1894	499
St. Louis Smelt & Ref	1897-1933	716,278
Union Lead Co.	1900	22
Columbia Lead Co.	1900-1904	11,713
Derby Lead Co.	1902	336
Irondale Lead Co.	1902	498
Federal Lead Co.	1902-1923	721,303
Total:		8,159,240

Milling Practices. During 1947 St. Joe operated four mills in the Old Lead Belt with a total rated capacity of 24,300 tons per day, divided as follows: Federal, 12,000 tons; Leadwood, 4800 tons; Desloge, 3600 tons; and Bonne Terre, 2400 tons. The four concentrators were of similar design.

To produce the millions of tons of pig lead generated during the 100-plus years of mining operations, many mine shafts were opened and then closed. Figure 2-1 shows the large number of shafts which were developed during this period.

2.3 Early History of the Sites

The first record of mining in St. Francois County is of Mine-a-Gebore, where operations were conducted on a small scale between 1742 and 1762. Mine-a-Layne was discovered about 1795, Mine-a-Manteo on the Big River in 1799, and Mine-a-la Plate about the same time. This early mining was entirely for chunk galena found in the residuum, which required no milling.

The modern history of lead mining, leading to the opening of the Lead Belt in St. Francois County, began on a 946-acre tract of land, located at the present site of the community of Bonne Terre. The site was known as La Grave Mines. On May 2, 1864, the St. Joseph Lead Company (St. Joe) purchased this tract of land, and mining began in open pits that gradually sloped downward until the operation developed into an underground mine; shafts were later sunk for better access to the ore.

In 1869 the first diamond drill was brought to Bonne Terre. Through its use, large bodies of ore were discovered that assured the development of the area as a great mining district. As many as 15 companies were in production during the early years, from the 1860s to the early 1900s. The St. Joseph Lead Company gradually acquired the holdings of these companies and became the only operator in the district in 1933. Mine output from St, Francois County reached a peak in 1942 when the concentrate equivalent of 197,430 ton of lead metal was produced. Table 2-1, above, lists total mine production for St. Francois County by year of operation.

Because mining was conducted at numerous locations within St. Francois County, and in order to properly focus the RI and any subsequent studies or actions, the RI site will be defined as including historic mining, milling, and smelting facilities operated within St. Francois County and will specifically include the following identifiable sites where mining, milling, and/or smelting are known to have occurred:

- Desloge
- National
- Leadwood
- Elvins/Rivermines
- Bonne Terre
- Federal
- Doe Run
- Hayden Creek

Division of the St. Francois County "site" into specific mining impacted sites is consistent with USEPA's actions in other mining districts, including Cherokee County, Kansas, and Jasper County, Missouri.

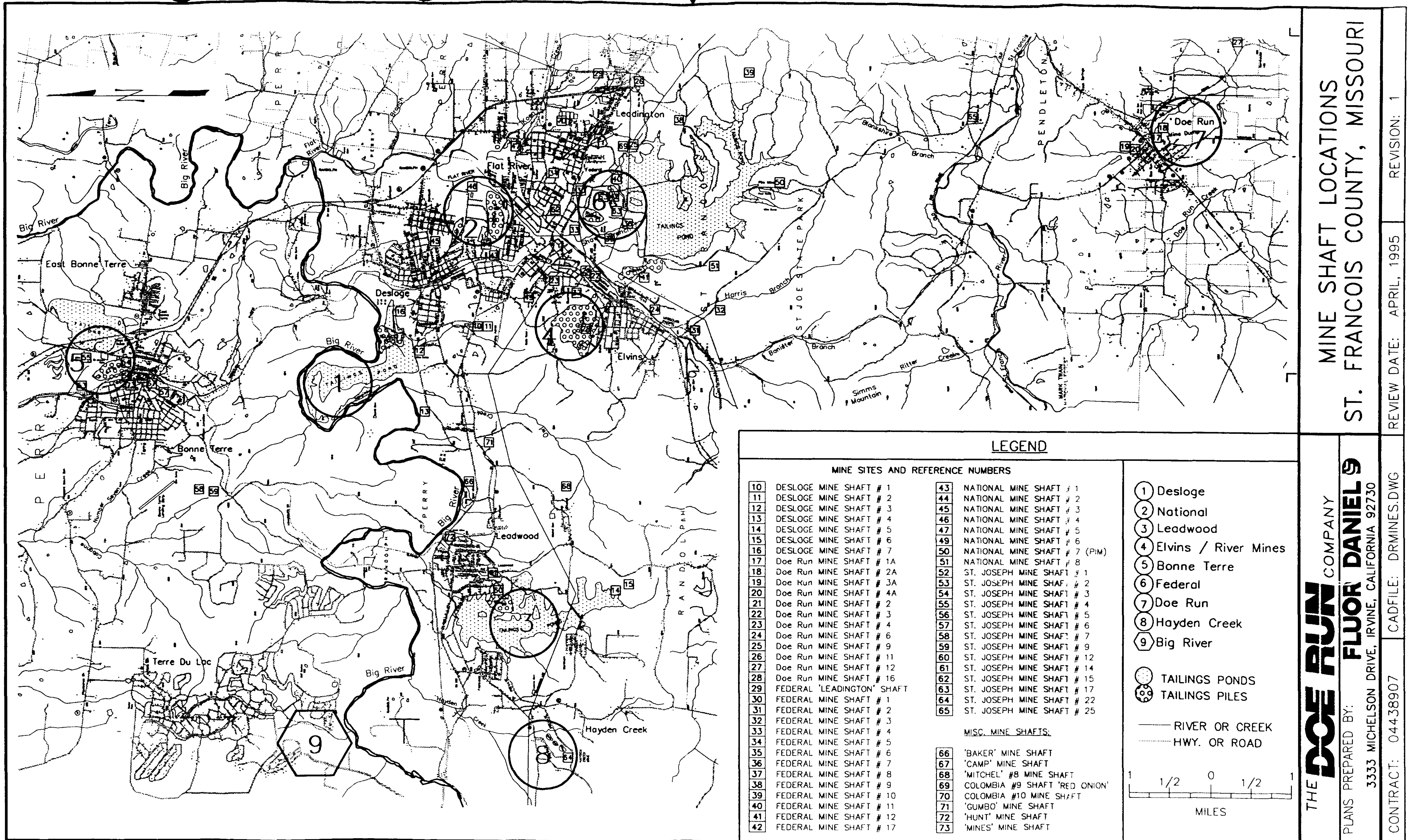

MINE SHAFT LOCATIONS
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CONTRACT: 04438907
CADFILE: DRMINES.DWG
LEGEND
MINE SITES AND REFERENCE NUMBERS
10 DESLOGE MINE SHAFT # 1
11 DESLOGE MINE SHAFT # 2
12 DESLOGE MINE SHAFT # 3
13 DESLOGE MINE SHAFT # 4
14 DESLOGE MINE SHAFT # 5
15 DESLOGE MINE SHAFT # 6
16 DESLOGE MINE SHAFT # 7
17 Doe Run MINE SHAFT # 1A
18 Doe Run MINE SHAFT # 2A
19 Doe Run MINE SHAFT # 3A
20 Doe Run MINE SHAFT # 4A
21 Doe Run MINE SHAFT # 2
22 Doe Run MINE SHAFT # 3
23 Doe Run MINE SHAFT # 4
24 Doe Run MINE SHAFT # 6
25 Doe Run MINE SHAFT # 9
26 Doe Run MINE SHAFT # 11
27 Doe Run MINE SHAFT # 12
28 Doe Run MINE SHAFT # 16
29 FEDERAL 'LEADINGTON' SHAFT
30 FEDERAL MINE SHAFT # 1
31 FEDERAL MINE SHAFT # 2
32 FEDERAL MINE SHAFT # 3
33 FEDERAL MINE SHAFT # 4
34 FEDERAL MINE SHAFT # 5
35 FEDERAL MINE SHAFT # 6
36 FEDERAL MINE SHAFT # 7
37 FEDERAL MINE SHAFT # 8
38 FEDERAL MINE SHAFT # 9
39 FEDERAL MINE SHAFT # 10
40 FEDERAL MINE SHAFT # 11
41 FEDERAL MINE SHAFT # 12
42 FEDERAL MINE SHAFT # 17
43 NATIONAL MINE SHAFT # 1
44 NATIONAL MINE SHAFT # 2
45 NATIONAL MINE SHAFT # 3
46 NATIONAL MINE SHAFT # 4
47 NATIONAL MINE SHAFT # 5
49 NATIONAL MINE SHAFT # 6
50 NATIONAL MINE SHAFT # 7 (PIM)
51 NATIONAL MINE SHAFT # 8
52 ST. JOSEPH MINE SHAFT # 1
53 ST. JOSEPH MINE SHAFT # 2
54 ST. JOSEPH MINE SHAFT # 3
55 ST. JOSEPH MINE SHAFT # 4
56 ST. JOSEPH MINE SHAFT # 5
57 ST. JOSEPH MINE SHAFT # 6
58 ST. JOSEPH MINE SHAFT # 7
59 ST. JOSEPH MINE SHAFT # 9
60 ST. JOSEPH MINE SHAFT # 12
61 ST. JOSEPH MINE SHAFT # 14
62 ST. JOSEPH MINE SHAFT # 15
63 ST. JOSEPH MINE SHAFT # 17
64 ST. JOSEPH MINE SHAFT # 22
65 ST. JOSEPH MINE SHAFT # 25
MISC. MINE SHAFTS:
66 'BAKER' MINE SHAFT
67 'CAMP' MINE SHAFT
68 'MITCHEL' #8 MINE SHAFT
69 COLOMBIA #9 SHAFT 'RED ONION'
70 COLOMBIA #10 MINE SHAFT
71 'GUMBO' MINE SHAFT
72 'HUNT' MINE SHAFT
73 'MINES' MINE SHAFT
1 Desloge
2 National
3 Leadwood
4 Elvins / River Mines
5 Bonne Terre
6 Federal
7 Doe Run
8 Hayden Creek
9 Big River
TAILINGS PONDS
TAILINGS PILES
RIVER OR CREEK
HWY. OR ROAD
1 1/2 0 1/2 1
MILES
Big River
East Bonne Terre
Bonne Terre
Desloge
Flat River
Leadington
Elvins
Leadwood
Terre Du Lac
Hayden Creek
Doe Run
Simms Mountain
Harris Branch
Blankshire Branch
ST JOE STATE PARK
TAILINGS POND

FIGURE 2-1

2.3.1 Desloge Site

Site History and Nature of Operations (Buckley, 1908)

The Desloge Lead Company operated on property near Bonne Terre between about 1877 and 1886. The Desloge Consolidated Lead Company operated on properties in the vicinity of Desloge between about 1890 and 1928.

The Desloge Lead Company, a family owned company, commenced mining operations in Bonne Terre about 1877 and sold its Bonne Terre operations to St. Joe about 1886. After 1886, the Desloge family acquired property near Desloge and commenced mining and milling operations at that location (the Big River Mine Tailings Site) under the name Desloge Consolidated Lead Company. St. Joe acquired Desloge Consolidated and the Desloge property and operation about 1928 and continued to operate at the site through about 1958.

As of about 1910, Desloge Consolidated owned about 4,800 acres of land in St. Francois County, most of which lay between the Desloge and Leadwood stations on the Mississippi River and Bonne Terre railroad. Desloge Consolidated purchased the original tract of about 2,100 acres from the Bogy Lead and Mining Company. As of 1910, there was present on Desloge property six shafts, a concentrating plant, roasters, furnaces, and a lead refinery. In 1910, three of the six shafts were being operated. The No. 1 shaft was sunk deeper and worked for a while after the property was purchased from Bogy, but when shaft No. 2 was sunk on the same ore body, No. 1 was abandoned. In sinking Shaft No. 5, such an inflow of water was encountered that it was subsequently abandoned.

In the early 1800s lead was mined from shallow depths at several places on land subsequently owned by Desloge Consolidated. The best known diggings went by the name of Mine-a-Joe, and the land upon which they were located was later prospected by Bogy and came to be known as the "Bogy tract." The shallow diggings were reported to have been very rich, the ore bodies lying in an east and west belt about 300 feet wide and over a mile long. The galena occurred embedded in red clay filling crevices and lining the walls and roofs of caves and other horizontal openings along bedding planes. There was no way of estimating the quantity of galena obtain from the shallow mines through 1887, the time at which Desloge Consolidated came into possession of the property.

From 1894 (the first record of production by Desloge Consolidated) to December 31, 1906, there was produced from the Desloge site disseminated deposits of about 115,367 short tons of concentrates.

The nature of Desloge's operations is summarized in the following chronology.

<u>Year</u>	<u>Report</u>
1889	"... the Desloge Consolidated Lead Company is prospecting a tract of 2,300 acres of magnesium limestone similar to the Bonne Terre formation ... a shaft has been sunk to a depth of 220 feet ...."
1891	"The mineral recently discovered on Flat River has interested a number of parties ... Desloge Consolidated Lead Company having already sunk a shaft which is producing ore ... This company owns about 2,100 acres of mineral lands lying between Big River and Flat River. One shaft has been sunk ...."
1894	"The Desloge Consolidated Company ... has its mine situated about one mile west of Desloge station on the M.R.&B.T.R.R. ... The land on which this company is now operating was first prospected by the Bogy Lead Mining Co...."
1898	"The Desloge Consolidated Lead Company ... in 1892 controlled 2,100 acres of mineral land ... it operates two shafts ...."
1899	"Desloge Consolidated Lead Company - The property of this company is located about four miles south of Bonne Terre ... This property was formerly known as 'The Mine a Joe or Bogy Mine' on which mining commenced in 1801 ...."
1901	"The Desloge Consolidated Lead Company smelts the greater part of its concentrates locally, but also ships a considerable part to custom smelters."

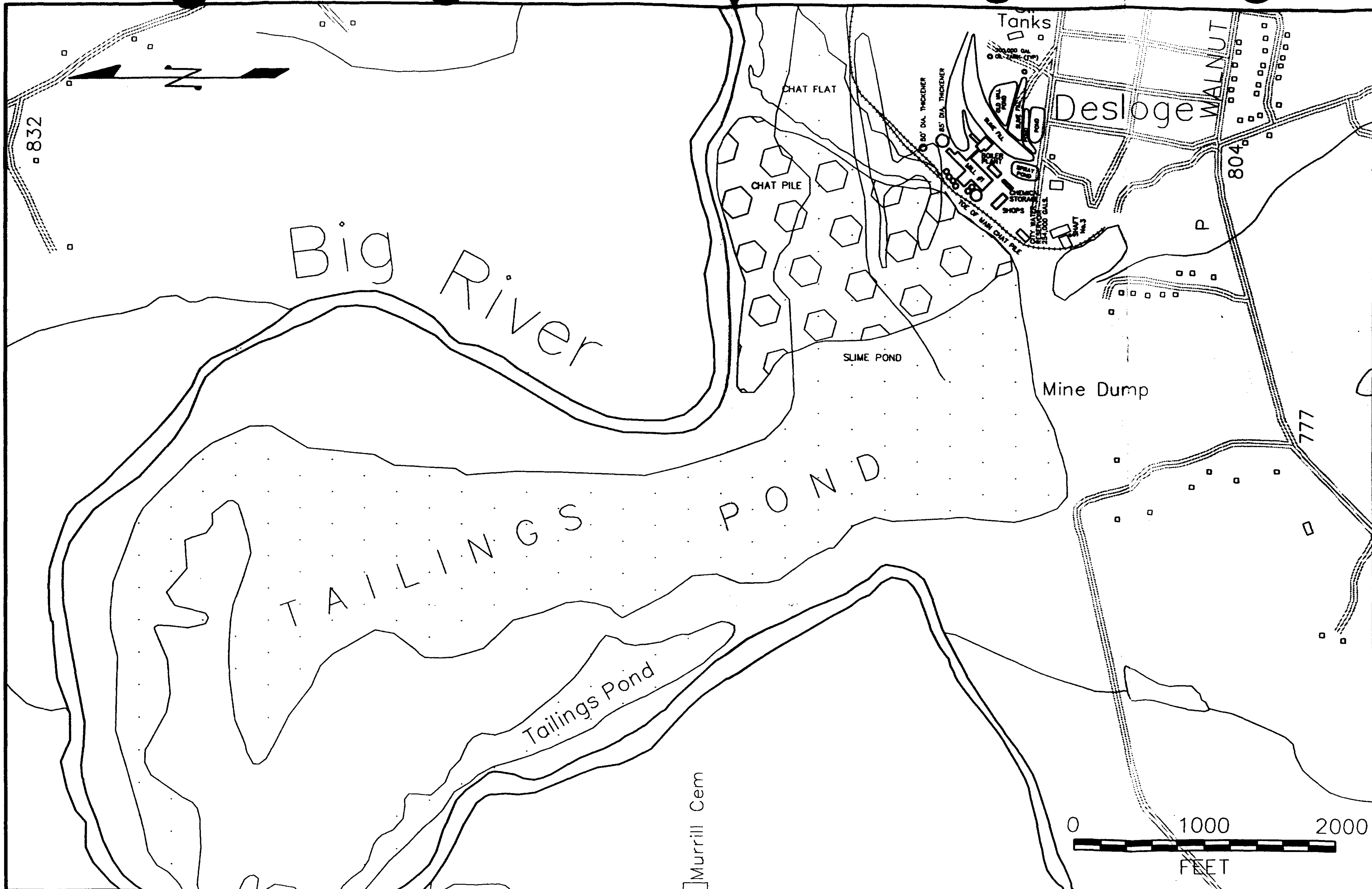
Year	Report
1903	"St. Joe, Doe Run, Desloge, Central and Mine La Motte companies produced 44,545 tons in 1903 as compared with 41,192 tons in 1902 and with 35,132 tons in 1901. In the case of the Desloge company this includes some lead smelted on contract by custom smelters ... Desloge Consolidated Lead Company ... owns 3,881 acres of land in the mineral belt of St. Francois county ... Three mines were operated during the year ...."
1903	"The Desloge Consolidated Lead Company is also building a new mill which will add materially to its capacity."
1904	"The Desloge Lead Company has sunk a new shaft, and has increased its mill capacity by 50 per cent. The company smelts only a part of its product, selling the remainder."
1906	"The Central mine was unwatered and ... considerable new ground was added to the property. New shafts were sunk by the Central, St. Joseph, Desloge and National companies, and a modern 1,000 ton mill was erected at the Central mine."
1923	"Desloge Consolidated Lead Company ... owns 4,704 acres of land ... During the past year the company has operated three shafts ...."
1924	"Desloge Consolidated Lead Company ... has been operating three shafts; at the present time they are sinking a mill shaft so they can hoist direct into the crushing plant ... The mill has a capacity of 1,600 tons daily."
1929	"An important change occurred during the year when the St. Joseph Lead Company took over the properties of the Desloge Consolidated Lead Company at Desloge, about the middle of the year."
1947	"In St. Francois County [St. Joseph Lead Company] continued in 1947 to operate four large groups of mines -the Bonne Terre, Desloge, Federal and Leadwood ... The combined daily capacity of the four mills at the end of 1947 was more than 22,000 tons. Treatment is by table concentration followed by flotation."

Year	Report
1950	"St. Joseph Lead Company ... operated its group of mines and four mills (Bonne Terre, Desloge, Federal and Leadwood) in St. Francois County ... These mills have a combined daily capacity of 26,800 tons. Mineral separation is by gravity methods followed by flotation."
1955	"St. Joseph Lead Company ... operated its Bonne Terre, Desloge, Federal and Leadwood mine-mill units, its Doe Run and Hayden Creek mines in St. Francois County (ore milled at the Federal and Leadwood mills) ...."
1956	"St. Joseph Lead Company operated its Federal, Bonne Terre, Desloge and Leadwood mills in St. Francois County."
1957	"St. Joseph Lead Company operated ... its Federal, Bonne Terre, Desloge and Leadwood mills in St. Francois County."
1958	"The Desloge mill was shut down on June 16 ...."

Figure 2-2 shows the historical location of mining-related facilities, including mills, tanks, shafts, roads, and disposal access.

Desloge's early operations were further characterized by Buckley (1908):

> "<u>Mines No. 1 and 2.</u> These shafts were located in the north east quarter of Section 1, Township 36 North, Range 4 East, otherwise described as the southeast quarter of Land Grant No. 870. They were about 800 feet apart. Shaft No. 2 was a little east of Shaft No. 1. Shaft No. 1 was about 3,600 feet south and 35 degrees west of Desloge station on the Mississippi River and Bonne Terre railroad. This shaft was sunk in 1873 by Bogy to a depth of 224 feet. Desloge Consolidated began prospecting this land in 1887 and began operations in Shaft No. 1 in 1890. The ore taken out was placed in a stock pile to await the building of the mill, which was started May 1893. During early 1892, the company began sinking Shaft No. 2 to connect with a drift from Shaft No. 1. The collar of this shaft was 840 feet above sea level.



HISTORICAL PERSPECTIVE OF
DESLOGE MINING FACILITY
ST. FRANCOIS COUNTY, MISSOURI

REVIEW DATE: APRIL, 1995

REVISION: 1

THE DOE RUN COMPANY

PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730

CONTRACT: 04438907

CADFILE: DRUSGS.DWG

FIGURE 2-2

"Mine No. 3. The shaft leading to Mine No. 3 was located about 3,300 feet a little north of west of Desloge station on the Mississippi River and Bonne Terre railroad. It was sunk in 1896. The collar of the shaft was 785 feet above sea level."

"Mine No. 4. The shaft leading to Mine No. 4 was located about 4,300 feet south and 83 degrees west of Shaft No. 3. It was about 500 feet south of the Big River and 900 feet west of Owl creek. The collar of this shaft was 760 feet above sea level. The sinking of this shaft was begun in 1902 and the first ore was hoisted in 1903."

"Mines No. 5 and 6 Shaft No. 5 was located near the line between the northeast quarter and the northwest quarter Section 9, Township 36 North, Range 4 East, about a half mile south of Leadwood. This shaft was abandoned before completion and Shaft No. 6 was started 1,000 feet southeast of Shaft No. 5. This shaft was completed to a depth of 494 feet. Shaft No. 5 was started at an elevation of 890.72 feet above sea level, while the collar of shaft No. 6 was 903.72 feet above sea level."

Site Facilities and Operations

Summarizing from the above:

1. Mining commenced at Desloge in 1890. Early operations at the site included mining, milling, roasting, and smelting.

2. Ore feed to the Desloge mill was from multiple mines (shafts) in the Desloge and nearby areas. Ore was hauled to the Desloge mill from remote locations by rail.

3. Roasting and smelting of ores at the Desloge site continued until about 1929 when the property was acquired by St. Joe.

4. The Desloge mill was from time-to-time modernized and enlarged. The mill was permanently closed in 1958.

2.3.2 National Flat River

Site History and Nature of Operations (Buckley, 1908)

The area was purchased by St. Joe from the National Lead Company in 1936. From all available records St. Joe did not operate the mill on the property.

As of about 1910, the St. Louis Smelting and Refining Company, a subsidiary of the National Lead Company, owned 1284 acres of land, all of which was located within a radius of two miles of Flat River station of the Mississippi River and Bonne Terre railroad. According to available reports, this property was purchased from the Flat River Lead Company in May 1898. At that time there was one shaft on the property, now known as Shaft No. 1. This shaft has a depth of 332 feet. In 1894, the Flat River Lead Company produced 750 tons of concentrates. This was the only production prior to the purchase by National as, not long after Flat River began operations, the mine workings were flooded.

National purchased 600 acres of land from Mr. Wm. R. Taylor, in addition to that obtained from the Flat River Lead Co. All of this land was prospected with a diamond drill before being purchased. National began sinking Shaft No. 2 in August 1898, and the first production was during July 1900. As of about 1910, National had five shafts on its property, four of which were being operated. Shafts No. 1 and 2 were located on the same ore body, about 690 feet apart. The mine workings at No. 1 and 2 were connected underground with Mine No. 3. Mines No. 4 and 5 were each separate. All of the ore obtained from these several mines was concentrated at a mill, located just east of the office. Concentrates were shipped to National's smelter at Collinsville, Illinois. The mill had a daily capacity of 1,600 tons. According to Buckley, "there was produced from this property since the first shaft was sunk up to Dec. 31, 1906, 100,545 short tons of concentrates ...."

The nature of operations at National are summarized in the following chronology.

Year	Report
1894	"The Flat River Lead Company - The property of this company embraces 1295 acres of land, all in one body, and is located in the great Flat River district ... The working plant is a complete one, embracing hoisting engines, ... twenty company houses, and the towns Leadville and Taylor Place."
1897	"The old works of the St. Louis Smelting and Refining Co. at St. Louis were again put in operation to smelt ores for southeastern Missouri and the Joplin district. From this time St. Louis increased rapidly in importance as a center of lead production."
1898	"The St. Louis Smelting and Refining Co., a constituent of the National Lead Co., acquired property in the disseminated district of Missouri and began its development, leading to a large production of lead in the course of a few years."
1899	"The St. Louis Smelting and Refining Company ... has secured possession of the old Taylor mines situated about one mile south of Desloge ... the present company has sunk a new shaft ...."
1900	"... The St. Louis Smelting and Refining Co. located at a station called Frisco on the M.R.&B.T.R.R.; has purchased what is known as the Taylor property, and has erected and equipped a plant ...."
1902:	"... St. Louis Smelting & Refining Company - The 1,200 acres of land owned by this company is located between the two large mining towns of Desloge and Flat River. The old Taylor Mine, extensively worked some years ago, is on the property, the same changing hands in 1897 ... The old Taylor shaft was abandoned and shaft No. 2 commenced in August 1898. Shaft No. 3 ... is located 2,400 feet north northeast of shaft No. 1 ... The plant was completed in July 1901."
1903	"... St. Louis Smelting and Refining ... owns 1,200 acres of mineral lands located between Desloge and Flat River ... Two mines were operated the past year ... The 176 jigs in this plant are divided into four distinct divisions ...."

Year	Report
1904	"The National Lead Company now ships the product of its Derby mines to the new smelter at Collinsville, Illinois. ...."
1906	"New shafts were sunk by the Central, St. Joseph, Desloge and National companies...."
1912	"The St. Louis Smelting & Refining Co. relinquished its lease of the Potosi Lead Co.'s mine near Leadwood and the mine was operated by the owners ...."
1913	"The St. Joseph Lead Company and the Doe Run Lead Company were merged under the name of the former company. The St. Louis Smelting and Refining Company ... received the crude ore from the Potosi Lead Co.'s mine for treatment."
1923	"The Pim tract, upon which there is a large body of ore, is being opened by the St. Louis Smelting & Refining Co."
1923	"... St. Louis Smelting and Refining Company ... owns 1,975 acres of mineral lands ... The company has a 2,500 ton concentration mill ... During the past year the company operated seven shafts ... During the past year the company sank and put into operation one of the deepest shafts in the history ... Federal Lead Company ... The company has twelve shafts including those purchased from the Central Lead Co. ... On October 23, 1923, the St. Joe Lead Co. purchased the entire holding of the Federal Lead Co. ... St. Joe Lead Company ... This company is divided into four divisions, namely, Bonne Terre Division, Leadwood Division, Rivermines Division and Federal Division ...."
1924	"St. Louis Smelting and Refining Company ... During the last year this company operated seven shafts ...."
1931	"The St. Louis Smelting and Refining Company ... operated its mines in St. Francois County a total of 238 days during the year; the St. Joseph Lead Company operated 222 days; the Doe Run Lead Company 224 days...."

Year	Report
1947	"In St. Francois County [St. Joseph Lead Company] continued in 1947 to operate four large groups of mines -the Bonne Terre, Desloge, Federal and Leadwood ... The combined daily capacity of the four mills at the end of 1947 was more than 22,000 tons. Treatment is by table concentration followed by flotation ...."
1955	"St. Joseph Lead Company ... operated its Bonne Terre, Desloge, Federal and Leadwood mine-mill units, its Doe Run and Hayden Creek mines in St. Francois County (ore milled at the Federal and Leadwood mills) ...."
1961	"St. Joseph Lead Company mined lead ore and operated its Bonne Terre, Leadwood and Federal mills. The company closed its Bonne Terre mine in August, its Bonne Terre mill in September and its National mine in October."
1975	"St. Joe Minerals Corp. donated 8,500 acres of land in St. Francois County to the State of Missouri for use as a state park ... The property ... is in the Flat River area of the Old Lead Belt on which St. Joe discontinued mining in 1970."

Figure 2-3 shows facilities associated with the early mining operations at National.

Early operations at National were further characterized by Buckley (1908):

> "Mines No. 1 and 2. The shaft at Mine No. 1 was sunk in 1893. During 1904, 750 tons of concentrates were produced, after which the mine was flooded and permanently abandoned. This shaft was sunk when the property was owned by the Flat River Lead Co. Owing to the shafts small size, it was not dewatered after the property was purchased by National. Shaft No. 2 was started in August 1898, and the first ore was hoisted in May 1900. This shaft was located about 825 feet east of the St. Francois station on the Mississippi River and Bonne Terre railroad. Shaft No. 1 was located 690 feet southwest of Shaft No. 2. The collar of Shaft No. 2 was 791.3 feet above sea level."

"Mine No. 3. This mine was located 2,700 feet north of the St. Francois station on the Mississippi River and Bonne Terre railroad and the same distance a little west of north of Shaft No. 2. The sinking of the shaft leading to Mine No. 3 was begun in June 1899. Mining operations began in May 1900. The collar of this shaft was 839 above sea level."

"Mine No. 4. The sinking of the shaft leading to Mine No. 4 was begun in June 1902. The first ore was hoisted from the in March, 1903. This shaft was located 2,740 feet north and 70 degrees east of No. 2. The collar of this shaft was 764.3 feet above sea level."

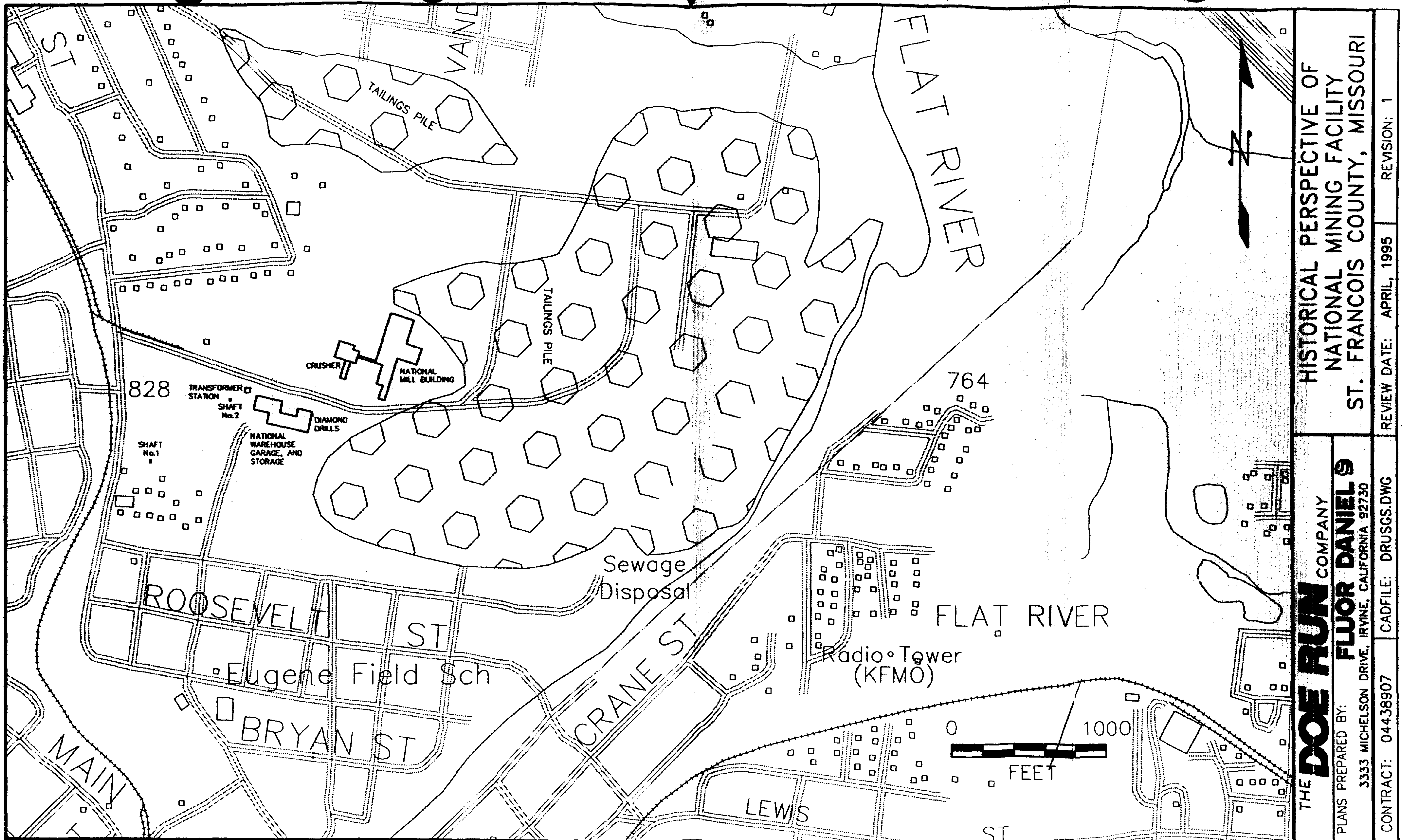
"Mine No. 5. This mine was located 5,130 feet south, and 72 degrees east of Mine No. 2,near the right of way of the Illinois Southern railroad. The sinking of Shaft No. 5 was begun in February 1906. National began hoisting ore from this shaft in March 1907. The collar of the shaft was at an elevation of 779.1 feet."

Site Facilities and Operations

Summarizing from the above:

1. Mining commenced at National in 1894. Early operations at the site included mining and milling.
2. Ore feed to the National mill was from multiple mines (shafts) in the Flat River and nearby areas. Ore was hauled to the mill from remote locations by rail.

3. The National mill was from time-to-time modernized and enlarged. The mill was permanently closed in 1936.



TAILINGS PILE
TAILINGS PILE
FLAT RIVER
CRUSHER
NATIONAL MILL BUILDING
828
TRANSFORMER STATION
SHAFT No.2
SHAFT No.1
DIAMOND DRILLS
NATIONAL WAREHOUSE GARAGE, AND STORAGE
764
Sewage Disposal
ROOSEVELT ST
Eugene Field Sch
BRYAN ST
MAIN
CRANE ST
FLAT RIVER
Radio Tower (KFMO)
0
1000
FEET
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ST
HISTORICAL PERSPECTIVE OF
NATIONAL MINING FACILITY
ST. FRANCOIS COUNTY, MISSOURI
REVISION: 1
REVIEW DATE: APRIL, 1995
CADFILE: DRUSGS.DWG
CONTRACT: 04438907
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730

FIGURE 2-3

2.3.3 Leadwood

Site History and Nature of Operations (Buckley, 1908)

St. Joe commenced mining in the Leadwood area in 1894. During 1903 it commenced construction of the Hoffman mill. The nature of St. Joe's operations at Leadwood is summarized in the following chronology.

Year	Report
1864	"Organization of St. Joseph Lead Co., which purchased La Grave mines at Bonne Terre. Active operations begun in 1865."
1890	"Completion of Mississippi River & Bonne Terre Railroad and removal by St. Joseph Lead Co. of its smelting furnaces from Bonne Terre to Herculaneum."
1894	"St. Joseph Lead Company ... property is situated in and around Bonne Terre ... Beside the mines immediately around the mill, the company is working two other shafts, known as Nos. 7 and 8 respectively, the first being about one mile southwest of the mill; the other being on what is known as the Crawley tract, situated on Flat River, about one mile east of the railroad station of that name ...."
1904	"The St. Joseph Lead Company, the largest individual producer of lead in the country, has gained in output by enlarging the Bonne Terre mill, by putting into partial operation a new mill at the Hoffman shaft which will be capable of handling 1,000 short."
1902	"St. Joseph Lead Company ... the following brief description ... mine No. 1 and mill at Bonne Terre ... Mine No. 3; Mine No. 4; Mine No. 5; Mine No. 6; Mine No. 7; Mine No. 8 or Crawley shaft; Mine No. 10, known as the Gumbo ... This mine is reached by a switch three and one half miles long leaving the main line at Elvins on the M.R.&B.T.R.R.... Mine No. 11 is on land ... that was owned by William and Thomas Hunt ... In speaking of this mine it is frequently called the 'Hunt Shaft'; Mine No. 12 The Hoffman ... is not yet in operation ...."

Year	Report
1903	"... St. Joe, Doe Run, Desloge, Central and Mine La Motte companies produced 44,545 tons in 1903 as compared with 41,192 tons in 1902 and with 35,132 tons in 1901 ... The St. Joseph Lead Company has been making extensive improvements in its mines and its smelting plant at Herculaneum, and is completing a large new concentrating plant at the Hoffman shaft ...."
1903	"St. Joseph Lead Company ... The company operated six mines during the year 1903 ... The company has an immense smelter located at Herculaneum ... where the ores from its own mines and those of the Doe Run Company are smelted ... Hoffman Mine (St. Joseph Lead Company) This is a new mine and mill site still in course of construction ...."
1904	"Description of the New Hoffman Mill ... built by the St. Joseph Lead Company during the years 1903-1904, is located at Owl Creek, about 4.5 miles west of Flat River. It has a capacity of about 1200 tons per 24 hours ...."
1904	"The St. Joseph Lead Company, the largest individual producer of lead in the country, has gained in output by enlarging the Bonne Terre mill, by putting into partial operation a new mill at the Hoffman shaft which will be capable of handling 1,000 short tons of ore per day ...."
1906	"The Doe Run Company decided to erect a 1,200- ton mill and the capacity of the new Leadwood smelter of the St. Joseph Company was increased by the addition of ten roasting furnaces."
1910	"The first new company to begin deep mining in this [southeast Missouri] district in several years is the Potosi Lead Company, which in early 1910, began a shaft near Leadwood."
1923	"On October 23, 1923, the St. Joe Lead Co. purchased the entire holding of the Federal Lead Co. The purchase price was $10,000,000 ... St. Joe Lead Company ... This company is divided into four divisions, namely, Bonne Terre Division, Leadwood

Year	Report
	Division, Rivermines Division and Federal Division ... In the course of 30 days they expect to have the Leadwood, Rivermines and Federal divisions cut together, making all three divisions one vast mine ... During the past year this company operated 25 shafts ...."
1947	"In St. Francois County [St. Joseph Lead Company] continued in 1947 to operate four large groups of mines -the Bonne Terre, Desloge, Federal and Leadwood ... The combined daily capacity of the four mills at the end of 1947 was more than 22,000 tons. Treatment is by table concentration followed by flotation ...."
1950	"St. Joseph Lead Company ... operated its group of mines and four mills (Bonne Terre, Desloge, Federal and Leadwood) in St. Francois County ... These mills have a combined daily capacity of 26,800 tons. Mineral separation is by gravity methods followed by flotation."
1955	"St. Joseph Lead Company ... operated its Bonne Terre, Desloge, Federal and Leadwood mine-mill units, its Doe Run and Hayden Creek mines in St. Francois County (ore milled at the Federal and Leadwood mills) ...."
1956	"St. Joseph Lead Company operated its Federal, Bonne Terre, Desloge and Leadwood mills in St. Francois County ... Two new 9- by 12-foot rodmills were installed in the Leadwood mill ...."
1958	"About midyear, the Hayden Creek mine was closed indefinitely and equipment removed."
1960	"... St. Joseph Lead Company [operated their] Federal, Bonne Terre and Leadwood mills (St. Francois County)."
1961	"St. Joseph Lead Company operated ... its Bonne Terre, Leadwood and Federal mills in St. Francois County. The Bonne Terre mill, however, was permanently closed in September ... the Federal mill was converted to all flotation ...."

Year	Report
1961	"St. Joseph Lead Company mined lead ore and operated its Bonne Terre, Leadwood and Federal mills. The company closed its Bonne Terre mine in August, its Bonne Terre mill in September and its National mine in October."
1962	"St. Joseph Lead Company operated ... its Federal and Leadwood mills in St. Francois County until they were closed by strike on July 27, 1962."
1963	"More than two million tons of lead ores was mined at St. Joseph's Federal mine near Flat River. The ore was processed at the company operated Federal and Leadwood mills ...."
1975	"St. Joe Minerals Corp. donated 8,500 acres of land in St. Francois County to the State of Missouri for use as a state park ... The property ... is in the Flat River area of the Old Lead Belt on which St. Joe discontinued mining in 1970."

Mills and other historical mining facilities at Leadwood are shown in Figure 2-4.

Site Facilities and Operations

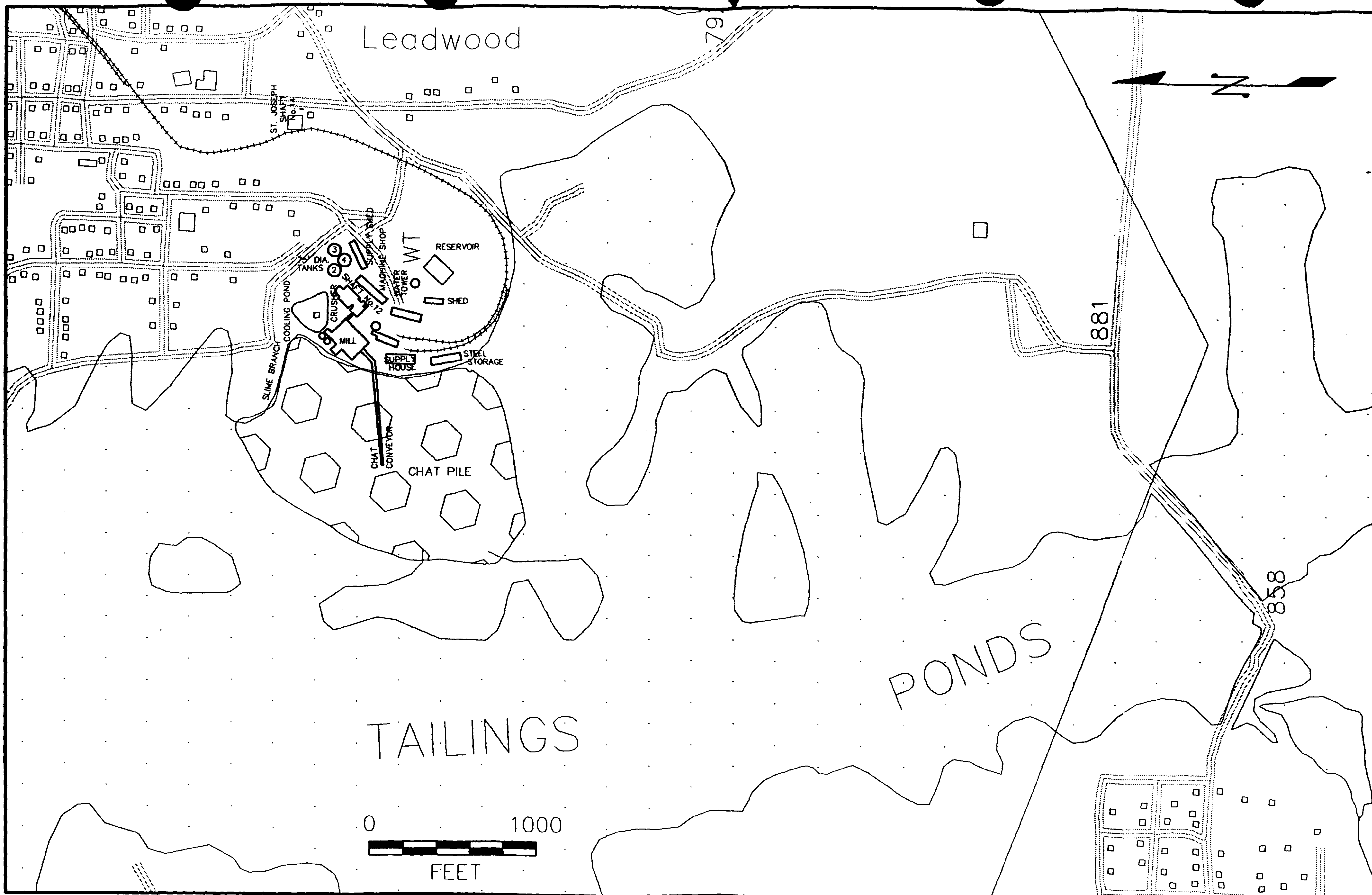
Summarizing from the above:

1. St. Joe commenced mining at Leadwood in 1894. Early operations at the site included mining, milling, and roasting.

2. Ore feed to the Leadwood mill was from multiple mines (shafts) in the Leadwood and nearby areas. Ore was hauled to the Leadwood mill from remote locations (early) by rail and (later) by truck.

3. Some roasting of ores may have continued at Leadwood through about 1920.

4. The Leadwood mill was from time-to-time modernized and enlarged. The mill was permanently closed about 1965.



HISTORICAL PERSPECTIVE OF
LEADWOOD MINING FACILITY
ST. FRANCOIS COUNTY, MISSOURI

REVIEW DATE: APRIL, 1995 | REVISION: 1

THE DOE RUN COMPANY

PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730

CONTRACT: 04438907 | CADFILE: DRUSGS.DWG

FIGURE 2-4

2.3.4 Elvins/Rivermines

Site History and Nature of Operations (Buckley, 1908)

The nature of operations at Elvins/Rivermines is summarized in the following chronology.

Year	Report
1864	"Organization of St. Joseph Lead Co., which purchased La Grave mines at Bonne Terre. Active operations begun in 1865."
1887	"Opening of Doe Run mine near Farmington"
1887:	"... The Doe Run Lead Company - Location of plant, northwest one-fourth of section 16, township 35, range 5 east; ... 1 incline and 1 vertical shaft; ... The mine is new and has been recently purchased by members of the St. Joseph Lead Company ...."
1889	"Development of disseminated ore at Flat River."
1890	"Completion of Mississippi River & Bonne Terre Railroad and removal by St. Joseph Lead Co. of its smelting furnaces from Bonne Terre to Herculaneum ... Practically, the make of soft lead is controlled by the operations of three great Missouri lead mining companies, the St. Joe, Doe Run and Mine La Motte ...."
1890	"The Saint Joseph Lead Company has built a narrow gauge railroad ... between Herculaneum and Bonne Terre, and is extending to Doe Run, and will soon be in a position to transfer its smelting operations to Herculaneum."
1891	"The mineral recently discovered on Flat River has interested a number of parties ... and shafts are being sunk by the Doe Run Lead Company ... Doe Run Lead Co. ... The company has recently purchased a large tract of mineral land on Flat River ... upon which two shafts are being sunk ...."
1894	"... Doe Run Lead Company - The mines of this company are situated at Doe Run ... the southern terminus of the M.R.&B.T.R.R.... The principal part of their ore is now coming

Year	Report
	from Flat River ... The shaft is 10 or 12 miles from Doe Run to which point the ore is taken for concentration ...."
1899	"... Doe Run Lead Company ... owns 4,000 acres of mineral land ... The mines of this company are located on its lands at Flat River Station, and its reduction works at the town of Doe Run ... Columbia Lead Company - This is a new company, with a new shaft ... The company owns 920 acres of land adjoining the lands of the Central Lead Company and the St. Louis Smelting and Refining Company. A shaft has been sunk ... this shaft and the mill ... 250 ton concentrating plant ...."
1900	"The third annual report of the Columbia Lead Company shows that since the mill was started on January 10, 1900, there were produced 3,444 tons of concentrates from 50,483 cars of crude ore, weighing about 1 ton each. During 1900 the company was engaged principally in sinking its No. 2 shaft to develop the Pim ore body ...."
1902	"Columbia Lead Company ... owns 944 acres of land near Flat River ... Two mines were operated during the year ... Doe Run Lead Company ... owns 4,000 acres of land ... There are three shafts of the property ... These shafts are located near Flat River ... with switches leading to each shaft ... The company was organized nineteen years ago ... [and] optioned at that time a portion of its present holding from Mr. Wm. R. Taylor, who had done some mining at Doe Run ... After Doe Run had drilled here for six or eight months ... it purchased the property ... A shaft was sunk, a very extensive mill erected, together with a number of calcine furnaces and a refinery ... the company [also] optioned a large body of land in the ... Flat River district ... The first property drilled ... was owned by King Williams. It then moved to ... the Crawley tract; thence to the Walton tract, on which ... it decided to sink a shaft ... The shaft was started ... a water channel was encountered ... this attempt was abandoned ... another shaft started about 1,000 feet distant ... After a lapse of another year, No. 2 shaft was started ... Following this another year found it sinking shaft No. 3 ... Following this shaft No. 4 was started ... No. 5 shaft sunk in four months."

Year	Report
1903	"The Federal Lead Company, which owns the Derby property, did not produce heavily, nor did the Commercial Lead Company, which has leased the Columbia Lead property, make its normal product."
1903	"Commercial Lead Company ... since June 13, 1903 has been in charge of the land and plant formerly known as Columbia Lead Company ... mines were then leased to the above named company ... Two shafts ... opened ore bodies which were worked during the year ... The third shaft was started during the year ... The company owns and operates a most complete plant ... Mill has a capacity of 250 tons ... Doe Run lead Company ... owns 4,000 acres of land in section 6, 7, 16, and 17, townships 35 and 36, ranges 4 and 5, St. Francois County ... Three mines were operated during the year ... The mines are located on company lands at Flat River, while its reduction works are located at Doe Run ...."
1904	" ... The Doe Run Company has operated to full capacity."
1906	"The Doe Run Company decided to erect a 1,200-ton mill and the capacity of the new Leadwood smelter of the St. Joseph Company was increased by the addition of ten roasting furnaces."
1909	"... Doe Run Lead Company ... owns and controls 6,548 acres of land in this county ... The mining operations of this company are carried on through seven shafts -Nos. 1 and 4 are at Flat River; Nos. 2 and 3 are at Central, about one fourth mile west of Flat River; Nos. 9 and 11 at Esther, two miles east of Flat River; No 6 at Elvins, one mile south; and no. 8 at Mitchell ... the new 2,000 ton mill at Elvins is worthy of special mention ...."
1911	"The milling capacity of the Flat River district has greatly increased during the past two years. In 1907, the Federal Lead Company completed the erection of a large concentrating plant having a capacity of 3,000 tons per day. The Doe Run Lead Company remodeled the plant located on the old Columbia Lead Company's property and are now erecting a large plant west of Elvins. This mill will have a capacity of 1,500 tons per day."

Year	Report
1913	"The St. Joseph Lead Company and the Doe Run Lead Company were merged under the name of the former company."
1915	"The Doe Run Company are erecting an additional section to their mill No. 3, the mill at Doe Run having been closed down."
1923	"... On October 23, 1923, the St. Joe Lead Co. purchased the entire holding of the Federal Lead Co. ... St. Joe Lead Company ... This company is divided into four divisions, namely, Bonne Terre Division, Leadwood Division, Rivermines Division and Federal Division ... In the course of 30 days they expect to have the Leadwood, Rivermines and Federal divisions cut together, making all three divisions one vast mine ... During the past year this company operated 25 shafts ...."
1924	"Doe Run Lead Company ... controls 6,998 acres of land ... The company operated five shafts ... Most of the mines are located near Rivermines, ..."
1931	"The St. Louis Smelting and Refining Company ... operated its mines in St. Francois County a total of 238 days during the year; the St. Joseph Lead Company operated 222 days; the Doe Run Lead Company 224 days ...."
1947	"In St. Francois County [St. Joseph Lead Company] continued in 1947 to operate four large groups of mines - the Bonne Terre, Desloge, Federal and Leadwood ... The combined daily capacity of the four mills at the end of 1947 was more than 22,000 tons. Treatment is by table concentration followed by flotation ...."
1950	"St. Joseph Lead Company ... operated its group of mines and four mills (Bonne Terre, Desloge, Federal and Leadwood) in St. Francois County ... These mills have a combined daily capacity of 26,800 tons. Mineral separation is by gravity methods followed by flotation ... Ore from two other shafts at Doe Run is trucked to the Federal mill."

Year	Report
1975	"St. Joe Minerals Corp. donated 8,500 acres of land in St. Francois County to the State of Missouri for use as a state park ... The property ... is in the Flat River area of the Old Lead Belt on which St. Joe discontinued mining in 1970."

Figure 2-5 shows the early mill and mining facilities at Elvins/Rivermines.

Site Facilities and Operations

Summarizing from the above:

1. Mining commenced at and near the Elvins/Rivermines site about 1890. Early operations included mining, milling, roasting, and smelting.

2. Doe Run commenced mining in the Flat River area in 1891. Early operations at the site included mining, milling, and roasting.

3. Subsequent to its entry into the Flat River area, Doe Run acquired existing properties, including those properties and operations of the Columbia Lead Company and Commercial Lead Company.

4. In early years, milling operations were conducted at numerous locations, including the properties and operations of the Columbia Lead Company and Commercial Lead Company.

5. By about 1909 milling at Elvins had been consolidated at one site.

6. Ore feed to the Elvins mill was from multiple mines (shafts) in nearby areas. Ore was hauled to the mill from remote locations by rail, above-ground (early), and under-ground (later).

7. The Elvins mill was from time-to-time modernized and enlarged. The mill was permanently closed about 1940.

2.3.5 Bonne Terre Site

Site History and Nature of Operations (Buckley, 1908)

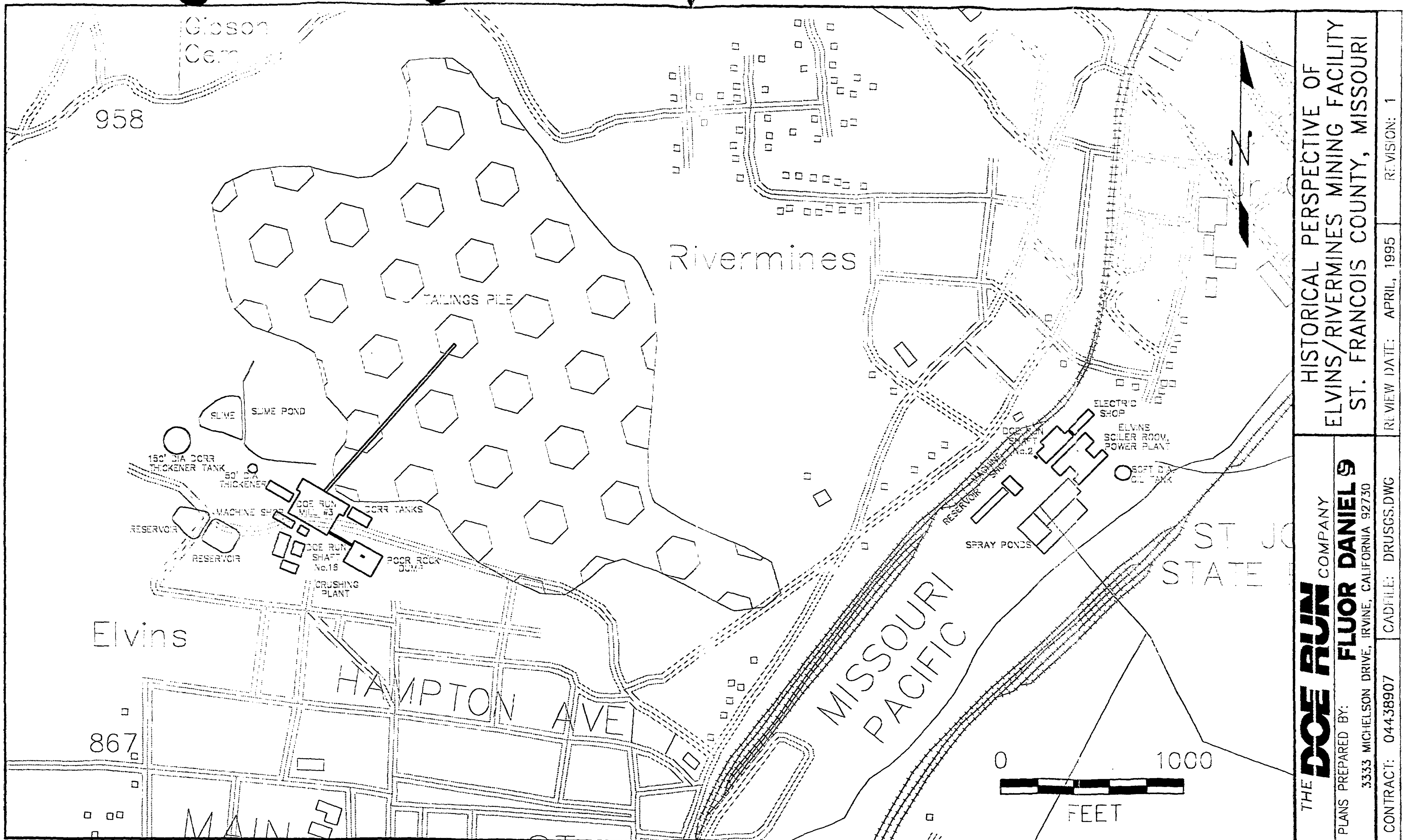
The St. Joseph Lead Company was organized in 1864 and began mining operations at Bonne Terre in 1865. The original tract of land owned by St. Joe was purchased from

Anthony La Grave. Prior to this, the property was owned by the Valle and Aubuchon families. Surface mining (diggings) was conducted in this locality prior to 1820, the earliest operations being carried out at what was known as the Pratt mine.

Upon taking charge of the property, St. Joe introduced many improvements, chief among which was prospecting with a diamond drill, which was inaugurated in 1869.

In 1880, a railroad was completed from this plant to Summit, a small station on the St. Louis, Iron Mountain and Southern Railroad. In 1883 the St. Joe Bonne Terre mill and associated works were almost completely destroyed by fire, after which a new and larger plant was erected. The Pen Diggings property, consisting of over 300 acres, was purchased in 1883, while in 1886, the adjoining Desloge Lead Company mines, which had been operated since 1877, were also purchased. (Note: The Desloge Lead Company operated on property near Bonne Terre between about 1877 and 1886. A separate company, Desloge Consolidated Lead Company, operated on properties in the vicinity of Desloge between about 1890 and 1928.)

The year 1800 marked the completion of the Mississippi River and Bonne Terre Railroad, which connected the St. Francois County lead mines with the St. Louis, Iron Mountain and Southern Railroad and the Mississippi River at Riverside. At about this same time, St. Joe completed construction of a smelting plant at Herculaneum, where all of the St. Joe ores were subsequently smelted, although part of the ores continued to be calcined by St. Joe at Bonne Terre, Leadwood and perhaps elsewhere in St. Francois County.



Gibson Cem
958
TAILINGS PILE
Rivermines
SLIME
SLIME POND
150' DIA DORR THICKENER TANK
50' DIA THICKENER
MACHINE SHOP
DOE RUN MILL #3
DORR TANKS
RESERVOIR
RESERVOIR
DOE RUN SHAFT No.16
POOR ROCK DUMP
CRUSHING PLANT
Elvins
HAMPTON AVE
867
MAIN
ELECTRIC SHOP
ELVINS BOILER ROOM, POWER PLANT
DOE RUN SHAFT No.2
MACHINE SHOP
RESERVOIR
SPRAY PONDS
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HISTORICAL PERSPECTIVE OF
ELVINS/RIVERMINES MINING FACILITY
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CADFILE: DRUSGS.DWG
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FIGURE 2-5

By about 1910, St. Joe had acquired rights to approximately 19,000 acres of mine and timber lands located mainly in St. Francois County. New shafts were sunk from time to time at Bonne Terre and on other St. Joe mine lands. By about 1908, the company had sunk 21 shafts. Nine of these were completed and used during the early production history of the company and were abandoned prior to about 1905. Figure 2-6 shows the historical mining facilities associated with the Bonne Terre site.

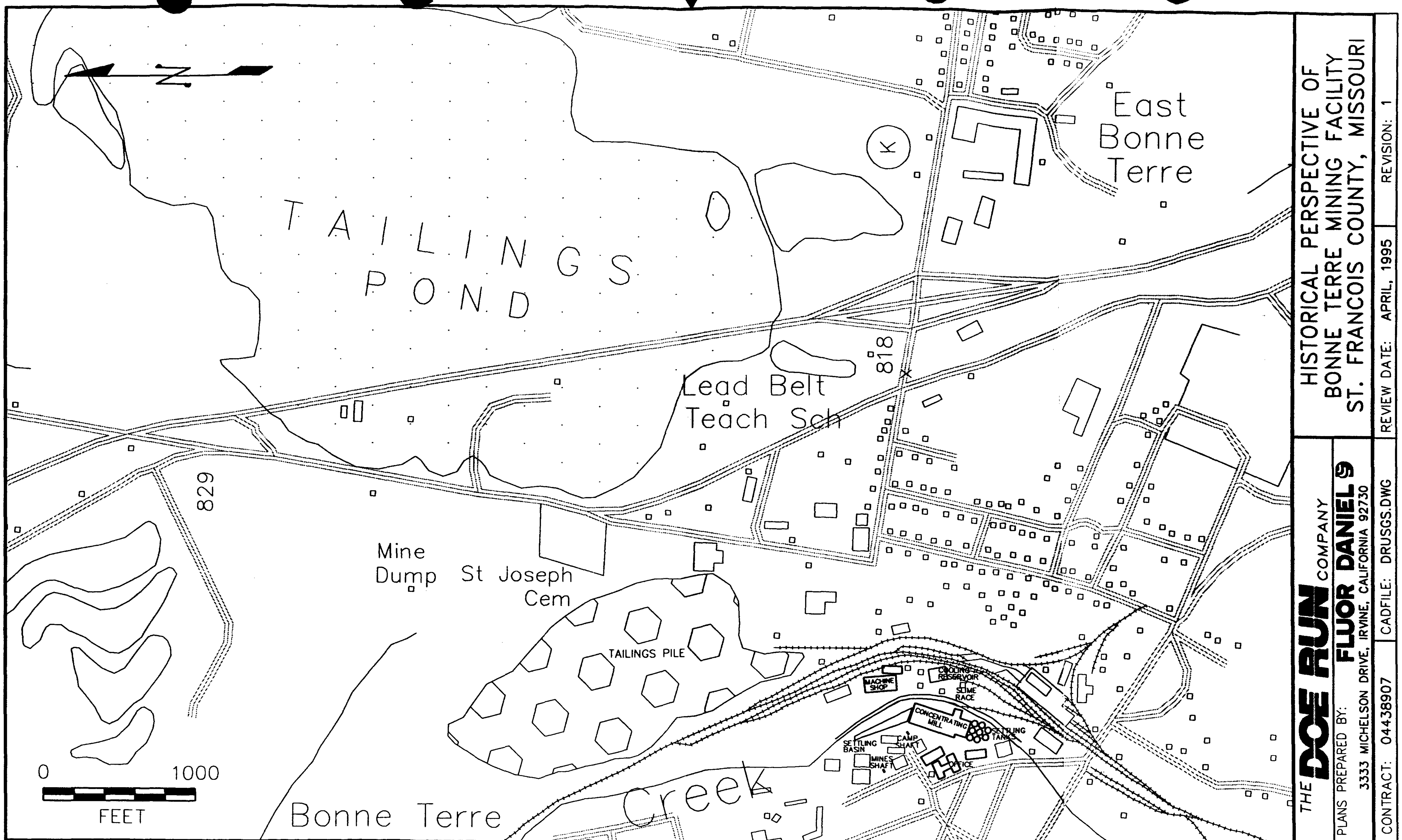
The nature of St. Joe's operations at Bonne Terre is summarized in the following chronology.

Year	Report
1864	"Organization of St. Joseph Lead Co., which purchased La Grave mines at Bonne Terre. Active operations begun in 1865."
1869	"Inauguration of diamond drill prospecting by St. Joseph Lead Co. at Bonne Terre, discovery of disseminated ore at depth."
1878	"Blast furnaces substituted for reverberatory at works of St. Joseph Lead Company."
1883	"Destruction by fire of mill and mine buildings of St. Joseph Lead Company, at Bonne Terre, replaced immediately by large and improved works."
1884	"Destruction by fire of works of Desloge Lead Co. at Bonne Terre, and purchase of mine by St. Joseph Lead Company."
1887	"At Bonne Terre, the Saint Joseph Lead Company is turning out lead at the rate of 13,500 tons a year, ... reduction works and principal shaft in section 14, township 37, range 4 east, St. Francois County ...."
1890	"Completion of Mississippi River & Bonne Terre Railroad and removal by St. Joseph Lead Company of its smelting furnaces from Bonne Terre to Herculaneum."

Year	Report
1891	"St. Joseph Lead company ... These mines are located at Bonne Terre ... During the past year 13,817.5 tons of pig lead were produced ... The following three mines were in operation ... Shaft No. 1 ... mine No. 4 ... Mine No. 5 ...."
1894	"St. Joseph Lead Company ... property is situated in and around Bonne Terre ... Beside the mines immediately around the mill, the company is working two other shafts, known as Nos. 7 and 8 respectively, the first being about one mile southwest of the mill; the other being on what is known as the Crawley tract, situated on Flat River, about one mile east of the railroad station of that name ...."
1904	"The St. Joseph Lead Company, the largest individual producer of lead in the country, has gained in output by enlarging the Bonne Terre mill, by putting into partial operation a new mill at the Hoffman shaft which will be capable of handling 1,000 short."
1961	"St. Joseph Lead Company operated ... its Bonne Terre, Leadwood and Federal mills in St. Francois County. The Bonne Terre mill, however, was permanently closed in September ... the Federal mill was converted to all flotation ...."

St. Joe's early operations were further characterized by Buckley (1908):

> "Present shafts No. 1, 2, 3, 4, 5, and 6, were all connected with the same ore body located at Bonne Terre. Likewise, the underground workings of the mines serviced by these shafts were all connected. The abandoned shafts were known as the Jones, Parsons, Hoadley, Cottonwood, Clare, Clinton, Camp, Hathaway, Old No. 2, Pen Diggings, Old No. 4, Pump and No. 13 (Air shaft). Shafts No. 7 and 9 were located about a mile and a quarter southwest of Mine No. 1. They were, however, in the same general area as the main workings of the St. Joe mines.
>
> "At Bonne Terre, Shaft No. 8, commonly known as the Crawley was located about three-fourths of a mile almost due east of the Flat River station on the Mississippi River and Bonne Terre Railroad. Shaft No. 10, known as the Gumbo, was located in the North West 1/4 of Section 2, Township 36N, Range 4E, about four miles south of Mine



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TAILINGS POND
East Bonne Terre
K
818
Lead Belt Teach Sch
829
Mine Dump
St Joseph Cem
TAILINGS PILE
MACHINE SHOP
COOLING RESERVOIR
SLIME RACE
CONCENTRATING MILL
SETTLING TANKS
SETTLING BASIN
CAMP SHAFT
MINES SHAFT
OFFICE
0
1000
FEET
Bonne Terre
Creek
HISTORICAL PERSPECTIVE OF
BONNE TERRE MINING FACILITY
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CADFILE: DRUSGS.DWG
CONTRACT: 04438907

FIGURE 2-6

No. 1 and about 2 1/4 miles west of the St. Francois station on the Mississippi River and Bonne Terre Railroad. Mine No. 11, known as the Hunt, was located in the North West corner of Section 3, Township 36N, Range 4E, northeast of Leadwood near the Big River. Mines No's 12 and 14, known as the Hoffman shafts, were located at Leadwood, near the center of Section 4, Township 36N, Range 4E. All of these mines were connected by spurs or branches with the Mississippi River and Bonne Terre railroad.

"The mines at Bonne Terre consist of two groups, the first and most important being reached through No. 1, 2, 3, 4, 5 and 6 and the Jones, Parsons, Hoadley, Cottonwood, Clare, Clinton, Camp, Hathaway (Old No. 4), Old No. 2, Pen Diggings, Pump and Air (No. 13) shafts. This group of mines, the underground workings of which were all connected, were reached at one time or another through eighteen separate shafts. In addition to these 18, there were several shallow abandoned shafts, from which some ore was mined at an early date. These mines underlie the City of Bonne Terre. The second group of mines were about 1 1/4, miles southwest of Mine No. 1 and were reached through two shafts known as No. 7 and No. 9. The two groups were separate but the mines of each group were connected underground at one or more levels.

"The first group of mines was entered by a ladder way in the Camp shaft. The collar of this shaft was at an elevation of 800 feet. From the bottom of this shaft the lower workings were reached by stairways and foot- paths. Shafts 1, 2, 3, 4, 5 and 6 were used for hoisting ore to the surface."

Definite information as to when the early shafts were sunk was not readily available. As noted, St. Joe began operations in 1866 following a period of desultory shallow mining extending from before 1820.

Site Facilities and Operations

Summarizing from the above:

1. St. Joe commenced mining at Bonne Terre in 1865. Early operations at the site included mining, milling, roasting, and reverberatory furnace smelting.

2. The St. Joe Bonne Terre mill was destroyed by fire in 1883; a new, larger mill was immediately constructed.

3. In 1884 fire destroyed the adjoining Desloge Lead Company mill. St. Joe subsequently acquired the mines and integrated their production into that of its Bonne Terre mill.

4. Ore feed to the Bonne Terre mill was from multiple mines (shafts) in the Bonne Terre and nearby areas. Ore was hauled to the Bonne Terre mill from remote locations by rail.

5. Smelting of ores at Bonne Terre ceased about 1890, when St. Joe completed construction of its Herculaneum facility. Some roasting of ores may have continued at Bonne Terre through about 1920.
6. The Bonne Terre mill was from time-to-time modernized and enlarged. The mill was permanently closed in 1961.

2.3.6 Federal

Site History and Nature of Operations (Buckley, 1908)

The Federal Lead Company began operations in the Old Lead Belt in 1902, producing that year, from one shaft, 4,320 short tons of concentrates. Subsequent to its organization, the company acquired by purchase the properties formerly owned by the Irondale Lead Company, the Derby Lead Company, the Central Lead Company, the Missouri Lead Fields Company, and several other smaller tracts owned by companies and individuals. In all, by about 1910, the company owned the fee to nearly 16,000 acres of land in St. Francois and Washington counties. As of 1908 there were seven producing mines on Federal property, each of which was reached by a shaft equipped with hoisting appliances. Two additional shafts were completed in 1908. Buckley (1908) notes that there were four additional shafts on Federal property, all of which had been temporarily abandoned. In all, it would appear that in 1908 there were 10 shafts operating on Federal Old Lead Belt properties.

The nature of Federal's operations is summarized in the following chronology (Welch, 1991):

<u>Year</u>	<u>Report</u>
1891	"The mineral recently discovered on Flat River has interested a number of parties ... and shafts are being sunk by the ... Central Mining Company."
1894	"The Central Lead Company - This company is the owner of 1400 acres, situated in the very heart of this great Flat river basin ... In 1890 the company commenced the sinking of a shaft ... The shaft was completed to a depth of 380 feet in the summer of 1983 and in October the erection of hoisting plant and concentrator works was begun ... The Leadington Lead Company ... is one of the new companies in this section ... The mine is situated on part of what was formerly known as the 'McKee mines' and is about two miles distant (east) from Flat River ... This company was first known as the Farmington Prospecting and Mining Company, but in January 1894 changed its name ... one shaft on the property ... also have a mill of 100 tons capacity ...."
1898	"The Central Lead Company ... controls 1,600 acres of mineral lands, operates two shafts ... This company having purchased the property and plant of the Theorodore Lead Co., the following must be added to the property ... 184 acres of mineral lands, one shaft ..."
1899	"Organization of the American Smelting and Refining Co., which acquired a large number of the silver-lead smelting and refining works of the United States, Several of these were promptly dismantled ... Entrance of the Guggenheims, under the name of the Federal Lead Co., into the disseminated district of southeastern Missouri."
1899	"Central Lead Company ... owns 1,604 acres of land in the great Flat river mineral belt ... Prospecting was commenced in 1876 ... but not until 1890 did the company sink a shaft ... There are now two shafts in operation ... Union Lead Company -... has secured the property and plant of what was formerly known as the Donnelly Mining Company,

Year	Report
	embracing 520 acres of land and a 100 ton plant. This mine is about 2 miles southeast of Flat River Station on the M.R.&B.T.R.R. ...."
1900	"Organization of Guggenheim Exploration Company which acquired, among other things, the capital stock of the Federal Lead Co. and of the Missouri Smelting Company."
1900	"The Guggenheim Exploration Company was organized to take over the properties of M. Guggenheim's Sons in southeastern Missouri, including the Federal Lead Company ... The company also operates the mines and mineral lands of Union Lead and Oil Company, including the large area purchased from the Missouri Lead Fields Company."
1900	"The Cathrine Lead Company ... started its mill on December 1, 1900. There are fully equipped two shafts, distant about 1,000 feet from one another, the mine being connected with the mill by a ... tramway 9,125 feet long."
1901	"Absorption by the American Smelting and Refining Co. of the smelting interests of M. Guggenheim's Sons the latter becoming, however, the dominating factor in the amalgamated company. The American Smelting and Refining Co. assumed control of the lead market, fixing the price both for producers and consumers, and regulating the output by agreement with the large producers and by adjustment of its smelting charges in connection with small producers."
1901	"In southeast Missouri the principal increase in production, among the older mines, was with the Saint Joseph Lead Company and with the Central Lead Company. The latter company has put a new shaft in operation and has blown in a new furnace ... The Columbus Lead Company and the Catherine Lead Company make no pig lead ...."
1902	"... Central Lead Company ... owns 1,604 acres of land ... there are three mines on the tract ... Shaft No. 1 ... Roger's Shaft ... Theodore Shaft ... Federal Lead Company ... owns 500 acres of land in the Flat River district ... One shaft was operated during the year ... shaft No. 2 has been sunk ... located 1,000 feet east of Flat River and 1,900

Year	Report
	feet west of the mill and shaft No. 1 ... Derby Lead Company ... owns 6,000 acres of land, part which adjoins some of the fine mining properties in the Flat River district. The company has sunk two very deep shafts ... The shafts are located three quarters of a mile south of Elvins, a station on the M.R.&B.T.R.R. ...."
1903	"The Central Lead Company, in the Flat River District, is not expected to make so much lead in 1904 as was produced in 1903 ... The Federal Lead Company, which owns the Derby property, did not produce heavily."
1903	"Central Lead Company ... owns 1,604 acres of mineral lands in the Flat River district ... Three mines were operated during the year ... Federal lead Company ... mineral land owned by this company is located in St. Francois and Washington counties, the total amounting to 13,500 acres ... The Derby is known as Federal No. 2 ... ore from the Derby mine (distance about two miles) is brought by rail ... At present two mines are in operation ... When the plant at Federal No. 1 is completed its capacity will be about 1,200 tons per day ...."
1904	"Federal Lead Company ... commenced operations in 1900 ... the property, known as the Derby Lead Company [is] controlled by the Federal people ... one large concentrating plant performed all work required by the three mines in operation."
1904	"Central Lead Company produced 3,812 short tons of lead in 1904 ... The Central Lead Company has been sold to the American Smelters Security Company."
1905	"... in southeast Missouri, ... The Federal Lead Company which is controlled by the American Smelting and Refining Company, and which owns the Derby and Federal mines in the Flat River district ... acquired the mines, concentrator and smelting plant of the Central Lead Company. This company, when in full operation, has produced 5,500 tons of lead per year."

Year	Report
1906	"Madison Lead and Land Company - This company purchased the property of what was known as the Catherine Lead Company, which consisted of 1,580 acres of land adjoining the Mine La Motte property."
1906	"The Central mine was unwatered and ... considerable new ground was added to the property. New shafts were sunk by the Central, St. Joseph, Desloge and National companies, and a modern 1,000 ton mill was erected at the Central mine."
1911	"The milling capacity of the Flat River district has greatly increased during the past two years. In 1907, the Federal Lead Company completed the erection of a large concentrating plant having a capacity of 3,000 tons per day."
1912	"... the Madison Lead & Land Company leased the Catherine mine and mill to the Federal Lead Company."
1913	"The Federal Lead Company operated the Catherine mine."
1915	"During the past year the Mine, located near Fredericktown, has been re-opened by the Federal Lead Company. This mine was formerly operated by the Madison Lead and Land Company ... The magnetic plant of Federal Lead Company which burned in October 1912, will be rebuilt."
1923	"Federal Lead Company ... owns over 1,400 acres of mineral land ... At present this mill is treating 4,800 tons of ore ... The company has twelve shafts including those purchased from the Central Lead Co. ... On October 23, 1923, the St. Joe Lead Co. purchased the entire holding of the Federal Lead Co. The purchase price was $10,000,000 ... St. Joe Lead Company ... This company is divided into four divisions, namely, Bonne Terre Division, Leadwood Division, Rivermines Division and Federal Division ... In the course of 30 days they expect to have the Leadwood, Rivermines and Federal divisions cut together, making all three divisions one vast mine ...."

Year	Report
1947	"In St. Francois County [St. Joseph Lead Company] continued in 1947 to operate four large groups of mines - the Bonne Terre, Desloge, Federal and Leadwood ... The combined daily capacity of the four mills at the end of 1947 was more than 22,000 tons. Treatment is by table concentration followed by flotation."
1950	"St. Joseph Lead Company ... operated its group of mines and four mills (Bonne Terre, Desloge, Federal and Leadwood) in St. Francois County ... These mills have a combined daily capacity of 26,800 tons. Mineral separation is by gravity methods followed by flotation."
1955	"St. Joseph Lead Company ... operated its Bonne Terre, Desloge, Federal and Leadwood mine-mill units, its Doe Run and Hayden Creek mines in St. Francois County (ore milled at the Federal and Leadwood mills) ...."
1960	"... St. Joseph Lead Company [operated their] Federal, Bonne Terre and Leadwood mills (St. Francois County)."
1963	"More than two million tons of lead ores was mined at St. Joseph's Federal mine near Flat River. The ore was processed at the company operated Federal and Leadwood mills ...."
1975	"St. Joe Minerals Corp. donated 8,500 acres of land in St. Francois County to the State of Missouri for use as a state park ... The property ... is in the Flat River area of the Old Lead Belt on which St. Joe discontinued mining in 1970."

Figure 2-7 shows the historical facilities located at the Federal site.

Federal's early operations were further characterized by Buckley (1908):

> "Mines numbers 4 and 5 were connected with Mine No. 1 by means of underground tunnels and that the ore from these mines was conveyed by an electric haulage system to shaft No. 1 for hoisting. Mines Nos. 6 and 7 were also connected underground while

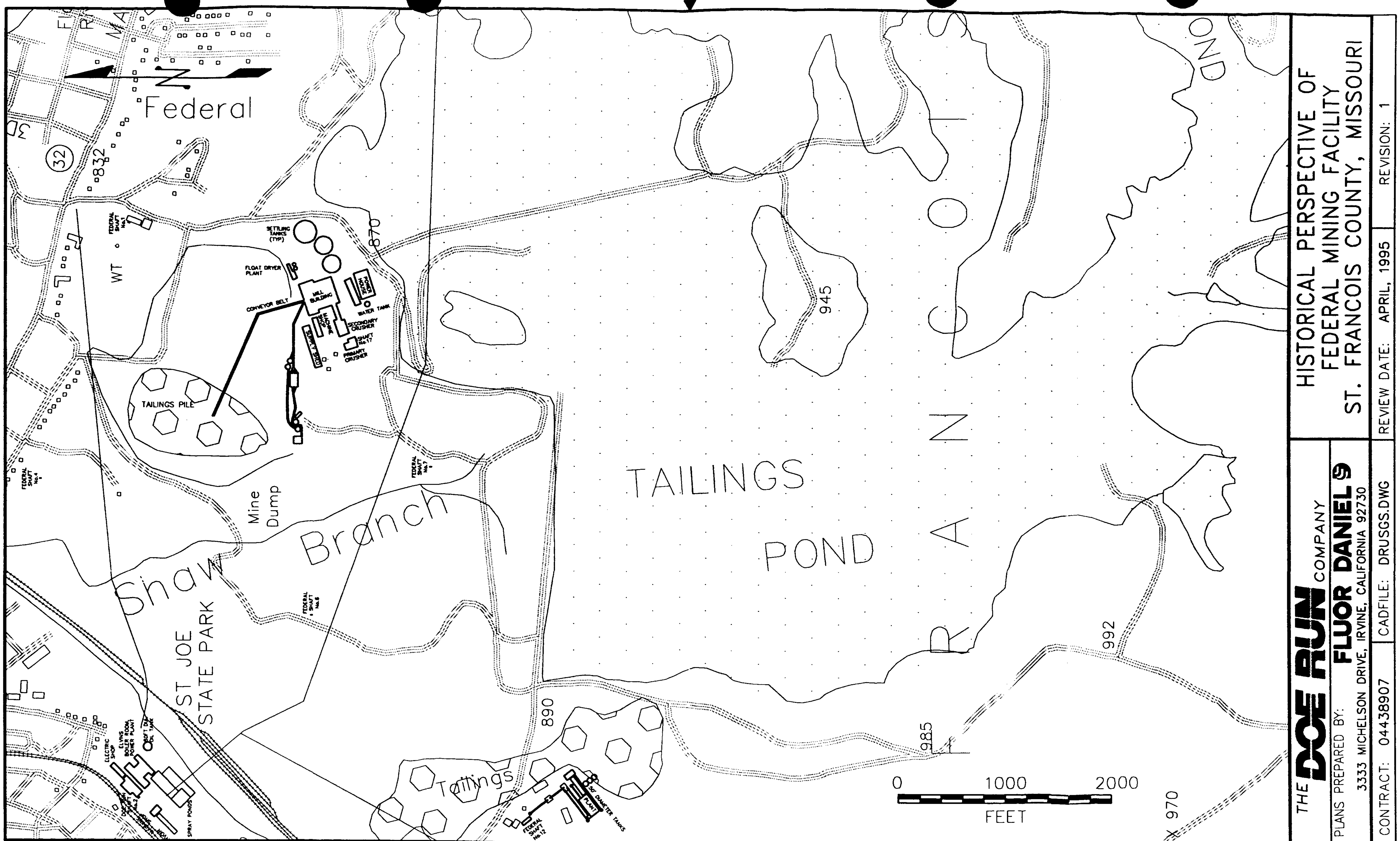
Mines Nos. 2, 8, 9 and 10 were separate, not being connected with any of the other mines. All these mines were each equipped with hoisting appliances. Mine No. 3, Buckley notes, was on the Derby tract, but had not been worked since Federal obtained possession of the land. The shaft was abandoned on account of a heavy flow of water encountered while sinking. The Murrell, the Irondale and the Leadington shafts were not operated by the Federal.

"Two mills, having a combined daily capacity of 3,200 tons, were being operated by Federal and that these mills were equipped with modern machinery and have, perhaps, the highest degree of efficiency of any in the district.

"There was produced by the properties now owned by the Federal Lead Company, including the Central Lead Co., The Irondale Lead Co., The Derby Lead Co., and The Leadington Lead Co., from 1894 to 1906, approximately 134,570 short tons of lead concentrates. Prior to 1894, shallow mining was carried on quite extensively at various places on Federal property but that it was difficult to make even an approximate estimate of the amount or value of the output.

"<u>Federal Mine No. 1</u> - This mine was equipped ready for operating in 1901, although the earliest reported production was in 1902. In the early days some shallow, or surface mining was done near the place where this mine was located. The only record that remains of these operations was an occasional cup or saucer like depression, scattered over some portions of the land surface, marking the location of shallow shafts. The collar of shaft No. 1 was 870.68 feet above sea level.

"<u>Federal Mines No. 2 & 3</u> - These shafts were on property which was formerly owned by the 'Derby Lead Company' and were formerly known as Derby No. 1 and 2. Number 3 shaft was reported to have been abandoned because the quantity of water entering the shaft was too great for the capacity of the pumps. This mine was first operated in 1902, during which year the company reported an output of 534 short tons of concentrates. Since that year the mine was operated almost continuously. The collar of the shaft was at an elevation of 806.7 feet.


Federal
32
832
870
WT
SETTLING TANKS (TYP)
FLOAT DRYER PLANT
MILL BUILDING
CONVEYOR BELT
WATER TANK
SECONDARY CRUSHER
PRIMARY CRUSHER
TAILINGS PILE
Mine Dump
Shaw Branch
ST JOE STATE PARK
TAILINGS POND
945
890
985
992
970
Tailings
GRANT COND
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HISTORICAL PERSPECTIVE OF
FEDERAL MINING FACILITY
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CADFILE: DRUSGS.DWG
CONTRACT: 04438907

FIGURE 2-7

"Mine No. 4 - The shaft of this mine was sunk in 1902. The shaft was located near Flat River about 3,000 feet a little north of west of shaft No. 1. The numerous mounds and cup like depressions on the hillside south of this mine give evidence of former activity in shallow mining in this vicinity. The collar of this shaft was 800.42 feet above sea level.

"Mine No. 5 - This mine was formerly owned by the Central Lead Company, having been acquired by them in 1898. It was located on a tract of land comprising 184 acres, then owned by 'The Theodora Lead Co.' With the other holdings of the Central Lead Company it passed into the hands of Federal in 1904. The shaft leading to this mine was situated about 2,000 feet North 20 degrees East of shaft No. 1. The collar of this shaft was 799.56 feet above sea level.

"Mines Nos. 6 & 7 - These mines were formerly owned and operated by the Central Lead Company. The shaft at mine No. 6 was known as the 'Central,' while that at Mine No. 7 was known as the 'Rogers.' The miners nicknamed the Rogers the 'Tumble Bug.' Shaft No. 6 was located about 2,580 feet South 37 degrees east of the Central station on the Mississippi River and Bonne Terre railroad. Shaft No. 7 was located about 1850 feet South 55 degrees east of shaft No. 6. These shafts were located on the same ore body and the mine workings were cut together. Hundreds of shallow mines were worked in close proximity to these shafts, mining having been carried on there as early as 1820. The so-called Butcher diggings were located on the property formerly owned by the Central Lead Company. These shallow mines were seldom over fifteen or twenty feet deep. An old shaft sunk by the Central Lead Company, prior to the sinking of the present shafts, followed a lead-bearing, clay filled crevice to a depth of sixty feet, where it opened into a large clay pocket containing massive galena. The crevice, although contracting to about one foot continued below the clay pocket, keeping a general east and west direction.

"This land was first prospected with a diamond drill in 1876, at which time some ore was encountered at a depth of 240 feet. A company was organized to develop the property but the attempt at that time was unsuccessful. However, in 1890, the company began sinking a shaft and at the same time resumed prospecting with a diamond drill. In May 1892 the shaft reached the ore body at the 242 foot level. In the meantime the diamond drill prospecting disclosed a richer and more extensive ore body at a depth of from 360 to 880 feet and it was decided to sink the shaft to this level. This shaft, the 'Central,' now 'Federal No. 6,' was completed during the Summer of 1893. The first production was in 1894. Shaft No. 7, formerly known as the 'Rogers,' was completed and in operation in 1901. From 1894 to 1904, when the Central Lead Company sold out to Federal, the total production, including that from the Theodora, was 38,700 short tons of concentrates. The collar of Shaft No. 6 was 791.84 feet above sea level and the collar of No. 7 shaft was 776.71 feet above sea level.

"Mine No. 8 - This mine was located just west of the Mississippi River and Bonne Terre Railroad depot at Central, on a forty acre tract which was a part of the land formerly owned by the Central Lead Company. The shaft was started in April, 1907. The collar of the shaft at Mine No. 8 was 781.53 feet above sea level.

"Mines Nos. 9 & 10 - Sinking of these shafts commenced in 1906. No. 9 shaft was located near the center of the South West 1/4 of Section 16, Township 36 North, Range 5 East, about 1 1/2 miles in a direct line southeast of shaft No. 1. Shaft No. 10 was located near the center of the North East 1/4 of Section 21, Township 36 North, Range 5 East, and nearly 2 1/2 miles directly southeast of shaft No. 1. Shaft No. 9 was started October 27, 1906, and shaft No. 10 December 15, 1906. The collar of No. 9 shaft was 1093.5 feet above sea level and the collar of No. 10 shaft was 1059 feet above sea level."

Site Facilities and Operations

Summarizing from the above:

1. Federal commenced mining in St. Francois County in 1902. Early operations at sites subsequently acquired by Federal included mining, milling, roasting, and smelting.

2. Subsequent to its entry into St. Francois County, Federal acquired existing properties including, at least, the properties and operations of Central Lead Company, Leadington Lead Company, Union Lead Company, and Derby Lead Company.

3. In early years, mining, milling, and perhaps smelting operations were conducted at numerous locations, including, at least, the properties and operations of Central Lead Company, Leadington Lead Company, Union Lead Company, and Derby Lead Company.

4. The Federal mill was destroyed by fire in 1912; a new, larger mill was subsequently constructed.

5. By about 1911, milling at Federal had been consolidated at one location (the Federal or St. Joe Park site).

6. Ore feed to the Federal St. Joe Park mill was from multiple mines (shafts) in nearby areas. Ore was hauled to the mill from remote locations by rail, aboveground (early) and underground (later).

7. Smelting of ores at Federal sites ceased about 1905. Some roasting of ores may have continued at some locations through about 1911.

8. The Federal mill was from time-to-time modernized and enlarged. The mill was permanently closed in 1965.

2.3.7 Doe Run

Site History and Nature of Operations (Buckley, 1908)

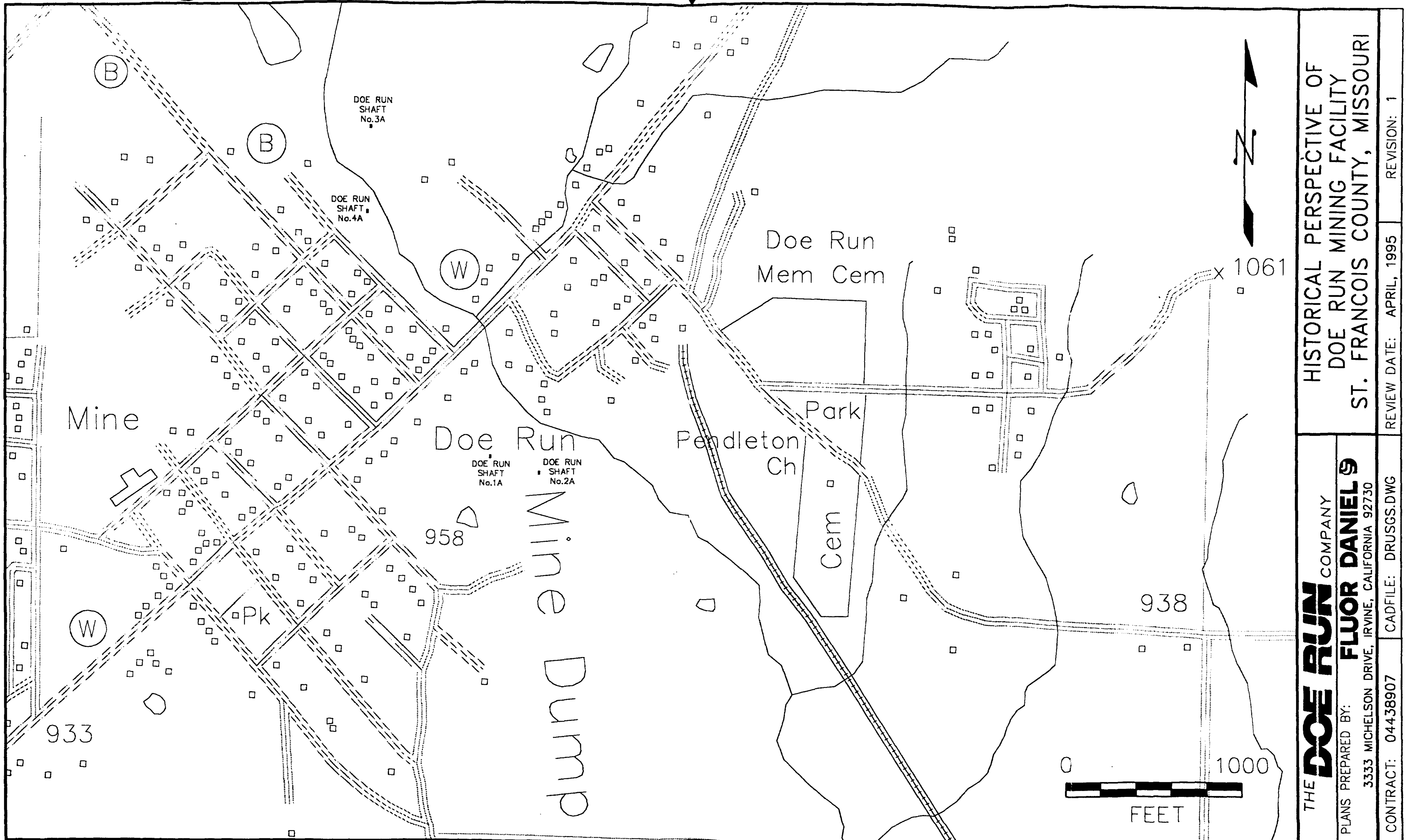
The Doe Run Lead Company was organized in 1887, the first reported production being 2,900 tons of concentrates in 1888. Prior to the organization of Doe Run, Mr. W. Range Taylor had sunk a shaft at Doe Run striking some disseminated lead ore at a depth of 40 feet. Doe Run optioned, drilled, and purchased the land, beginning active operations in 1887.

Doe Run sunk two shafts, one 110 feet, and the other 47 feet deep. The shafts were both close to where the pre-Cambrian granite outcrops, and the Bonne Terre dolomite, in some places, lies directly upon the granite, the Lamotte sandstone being absent. In some places a boulder conglomerate was found to lie between the dolomite and the granite.

About 1890 Doe Run purchased a large tract of land in the Flat River area. Before 1890 Doe Run acquired the properties formerly owned by the Union Lead Company and the Columbia Lead Company.

During 1892 Doe Run completed its first shaft in the Flat River area. By about 1908, Doe Run operated four shafts, two of which were located near the community of Doe Run and two in the Flat River area. The mines at Doe Run continued to supply ore until 1895, when they were practically abandoned. Figure 2-8 depicts the facilities at the Doe Run site.

The first shaft which Doe Run attempted to sink at Flat River was abandoned at a depth of 200 feet owing to heavy inflows of water. The second shaft, now known as Shaft No. 1, was 376.43 feet deep, and was completed in 1892. As of about 1910, Doe Run had 11 shafts on their property in the vicinity of Flat River. Six of these (No. 1, 2, 3, 4, 8, and 9) were active, while five had been abandoned. Another shaft was started near No. 8 in 1907, but work was suspended before it had progressed very far. The workings in Mines 1 and 4 were connected, as were those in Mines 2 and 3. Each of the other mines was reached by a single, three-compartment shaft. All of the operating shafts were equipped with hoisting appliances. Mine 6 was abandoned soon after the shaft was sunk, owing to the building of the Illinois Southern Railroad. Shaft No. 5 was a pump shaft, 90 feet from Shaft No. 4, which was sunk to drain the latter shaft after it had been inundated by an extremely heavy flow of water.



B
B
W
W
DOE RUN SHAFT No.3A
DOE RUN SHAFT No.4A
DOE RUN SHAFT No.1A
DOE RUN SHAFT No.2A
Mine
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958
933
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FEET
HISTORICAL PERSPECTIVE OF
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CONTRACT: 04438907
CADFILE: DRUSGS.DWG

FIGURE 2-8

Shaft No. 7 was an abandoned shaft near No. 2. One of the two remaining shafts was located on the property formerly owned by the Union Lead Company, and the other was formerly the No. 1 shaft of the Columbia Lead Company. The ore from these several mines was milled and roasted at Doe Run, where the company had its concentrating plant and furnaces. The material was shipped to Herculaneum, where it was refined at the plant owned by St. Joe. As of 1910, a new concentrating plant was being constructed southwest of the Central station on the Mississippi River and Bonne Terre Railroad, to supplement the one at Doe Run. The Doe Run plant had a daily capacity of 1100 short tons, while the new plant was to have a capacity of 1200 short tons.

Doe Run produced from its several properties, including those at Doe Run, up to December 31, 1906, about 213,000 short tons of lead concentrates. During the same period there was produced by the mines owned by the Columbia Lead Company approximately 18,100 short tons of lead concentrates. In 1900, the only year for which we have any record of production, the Union Lead Company produced .35 short tons of lead concentrates. This makes the total production of lead concentrates from the properties owned by Doe Run 231,000 short tons.

Information regarding the Doe Run site operations was presented by Buckley (1908) and is excerpted below:

> "Mine No. 1, This mine was opened in 1891 after an unsuccessful attempt to sink another shaft about 600 feet south. This shaft was only operated for a short time and then temporarily abandoned on account of excessive water. It was opened again in 1907. The collar of shaft No. 1 was 791.43 feet.
>
> "Mines No. 2 and 3, Shaft No. 2 was located approximately 3080 feet South, 12 degrees West of shaft No. 1, while shaft No. 3 was located, approximately 3630 feet south, 15 degrees west of shaft No. 1. Shaft No. 2 was on the east side of the tracks of the M. Range and B. Township railroad and just south of Central station, while shaft No. 3 was just west of the same tracks and about one-third of the distance between Central and Elvins stations. Shaft No. 2 was sunk in 1893. Shaft No. 3 was put into operation in 1898. At an early day surface diggings were operated near these deep

mines. The collar of shaft No. 2 was 758.98 feet above sea level and the collar of shaft No. 3 was 757.22 feet above sea level."

"Mine No. 4, Shaft No. 4 was located approximately 825 feet South 34 degrees East of No. 1. It was southeast of and near the Flat River station of the Mississippi River and Bonne Terre railroad. The mine workings were reached through two shafts (4 and 5) ninety feet apart. These shafts were sunk in 1899-1900. Shaft No. 4 was flooded soon after it was finished and No. 5 was sunk to unwater it. The collar of No. 5 shaft was 784.93 feet above sea level."

"Mine No. 6, This was represented merely by a shaft which was sunk to connect with an extension of the ore body from Mines No. 2 and 3. The laying of the Illinois Southern railroad tracks just west of the shaft resulted in its abandonment."

"Mine No. 8, This mine was located on what was known as the Mitchell tract and was near the center of the South West 1/4 of the North East 1/4, of Section 10, Township 36N., Range 4E. This mine was opened in 1907 and was operated less than a year. The collar of the shaft was at an elevation of 862.43 feet above sea level."

"Mine No. 9, This mine was on property purchased from the Columbia Lead Company and was known variously as the "Columbia No. 2," "Pim" and "Red Onion." It was located a little east of the middle and near the north line of Section 17, Township 36N, Range 5E. It was a little over 1 1/2 miles almost directly southeast of Doe Run No. 1. This mine was first put into operation in 1897 shortly after the sinking of Columbia No. 1. The shaft was located on what was known as the "Pim Tract" which lies east of Land Grant 32 then owned by the Federal Lead Company. The collar of the shaft was 904.54 feet above sea level."

"Columbia No. 1, The shaft was sunk in 1899 but operations were not started until January, 1900. This mine and the Columbia No. 2, were operated somewhat intermittently, having been leased at one time by "The Commercial Lead Company." During the period of its existence the Columbia Lead Company produced from its two mines about 18,112 short tons of concentrates. The collar of the shaft at Columbia

Mine No. 1 was about 800.00 feet above sea level. In the early days there were a great many shallow diggings near this mine."

Site Facilities and Operations

Summarizing from the above:

1. Mining commenced at the Doe Run site in 1888. Early operations at the site included mining, milling, roasting, and smelting.

2. Ore feed to the Doe Run mill was from multiple mines (shafts) in the Flat River area. Ore was hauled to the mill from remote locations by rail.

3. Smelting of ores at Doe Run ceased about 1890 when St. Joe completed construction of its Herculaneum facility. Some roasting of ores may have continued at Doe Run through about 1920.

4. The Doe Run mill was permanently closed in 1895.

2.3.8 Hayden Creek

Site History and Nature of Operations (Lane, 1957)

In contrast with most of the other operations in the district, underground haulage at Hayden Creek was entirely trackless. Nearly complete delineation of the ore body by drilling permitted comprehensive planning of development and mining in advance of shaft sinking. The ore differed in character and occurrence from that of the main ore deposits in the Old Lead Belt in that the lead mineral, galena, occurred in the dolomitic matrix enclosing granite boulders instead of in dolomite limestone.

The Hayden Creek mine was one of the newer operations in the Old Lead Belt. It was also referred to as the No. 22 mine because the shaft was the 22nd to be sunk in the district by St. Joe. The ore body was discovered by random diamond drilling in 1943, but systematic drilling to outline the ore did not begin until 1948. Shaft sinking began in May 1949 and underground development in July 1951.

The character and occurrence of the Hayden Creek ore body were unique. The ore occurred in a cemented granite boulder bed on the flank of a Precambrian granite knob, whereas most of the ore mined in the Old Lead Belt occurred in disseminated and bedding-plane deposits in the Bonne Terre dolomite.

Access to the mine was through a vertical shaft sunk in the country rock 40 feet from the west edge of the ore body. Underground development, which included excavation of a crusher room and the shop and supply rooms, began in July 1951. Mining began on a small scale in July 1952. The rate of output had increased to 1,000 tons of ore per day by June 1953 and averaged 1,303 tons per day during the last 6 months of that year. Production was cut back in October 1954 to a daily average of 1,000 tons and was subsequently maintained at that rate.

A 1,200-ton-per-day, magnetic-separation mill was originally constructed at the Hayden Creek site. The mill, however, failed to operated satisfactorily and by 1954 was permanently closed. Ore from Hayden Creek was subsequently hauled by truck to the St. Joe Leadwood mill for processing. Figure 2-9 depicts the facilities once located at Hayden Creek, including the mill and other historical facilities before they were demolished. The Hayden Creek mine was permanently closed in 1958.

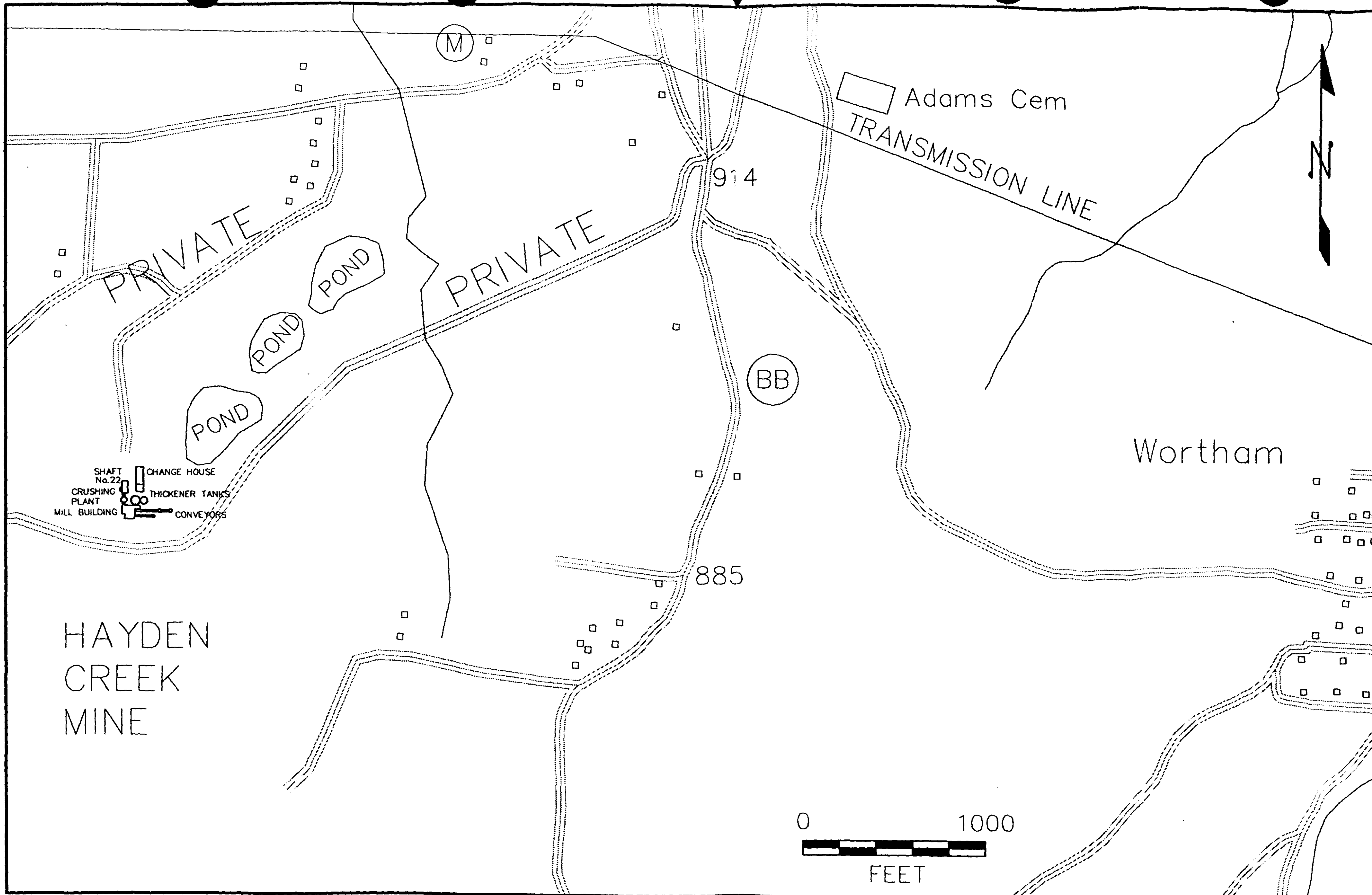
Site Facilities and Operations

Summarizing from the above:

1. St. Joe commenced mining at Hayden Creek in 1951. Operations at the site included only mining and milling.

2. The Hayden Creek mill was closed in 1954. Ore was subsequently trucked to the St. Joe Leadwood mill for processing.

3. The Hayden Creek mine was permanently closed in 1958.



HISTORICAL PERSPECTIVE OF
HAYDEN CREEK MINING FACILITY
ST. FRANCOIS COUNTY, MISSOURI

REVIEW DATE: APRIL, 1995 | REVISION: 1

THE DOE RUN COMPANY

PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730

CONTRACT: 04438907 | CADFILE: DRUSGS.DWG

FIGURE 2-9

2.3.9 Other Potential Sites

From the foregoing we note that milling, and perhaps smelting, was conducted from about 1890 through about 1920 at numerous locations in St. Francois County in addition to those specifically noted above. These additional locations would include:

- Desloge Lead Company site near Bonne Terre
- Central Lead Company site in the vicinity of Flat River
- Columbia Lead Company site in the vicinity of Flat River
- Donnelly Mining Company site in the vicinity of Flat River
- Derby Lead Company site in the vicinity of Flat River
- Flat River Lead Company site in the vicinity of Flat River

The exact location of these mills has not yet been determined. In general the mills were small, 100 to 250 tons per day, and the period of operation limited, one to ten years.

2.4 Mining, Milling, and Smelting - Operations and Technologies Used

As previously noted, up to 15 companies were in production from the 1860s to the early 1900s. The St. Joseph Lead Company gradually acquired the holdings of these companies and became the only operator in the district in 1933 working the mines through the early 1970s. This section describes the specific operations (Section 2.4.1), practices (Section 2.4.2), and technologies (Section 2.4.3) used at the BRMTS.

2.4.1 Specific Operations

The following descriptions of operations are excerpted from Buckley (1908):

Union Mining and Smelting Company (Union Lead Company)

In 1887 the Missouri State Mine Inspector (MSMI) reported: "The land owned by this company [Union Mining and Smelting Company] is known as the Old Mines concession, covering 6,700 acres in townships 38 and 39, ranges 2 and 3, east; character of ore, lead sulfide, with some lead carbonate, associated with baryte. The lead and baryte are found from the surface to a depth of 103 feet. The upper or float ore is found in clay, the lower, in clay pockets in magnesium limestone ... The company has one Scotch furnace, 2 "eyes"; 1 steam pump and boiler; about 50 men are mining on company land; output last year, 950,000 pounds of lead...."

In 1894 the MSMI reported: "This company (Central Lead Company) is the owner of 1400 acres, situated in the very heart of this great Flat river basin. Over 50 years ago surface mining for galena was here carried on with the primitive methods then known. In 1876 a diamond drill was procured and a few holes bored to a depth of 240 feet. Some ore was encountered and a corporation organized but at that time an effort to enlist sufficient capital to undertake development was unsuccessful. In 1890 the company commenced the sinking of a shaft ... The shaft was completed to a depth of 380 feet in the summer of 1893, and in October the erection of hoisting plant and concentrating works was begun. These were completed in May of this year [1894] ... the concentrating works have capacity of but 100 tons of ore daily ... The concentrates are shipped to the Pennsylvania Lead Company, Carnegie, Pa., where they are economically smelted with silver lead ores."

In 1898 the MSMI reported: "This Company ... controls 1,600 acres of mineral land, operates two shafts, 350 and 370 feet in depth, respectively, with equipment consisting of 10 steam boilers, 4 steam pumps, 3 air compressors, 2 steam hoisters, 3 crushers and 38 steam jigs ... During the month of October of the same year [1893], the erection of a hoisting plant and concentrating works were commenced, and the entire plant placed in working order in the spring of 1895 ... There are three mines on the tract with shafts of an average depth of 365 feet. ... The concentrating plant is equipped with ... an extra large chat tank, 34x36 feet ... A very large pump ... supplies a stream of clear water to the top of the mill ... This water then runs to the tables and jigs, as desired ... ore is conveyed to the mill from the mines by both horse and steam power, eighty seven cars being furnished for the purpose ... The excavated place in the mine has reached a great distance and it requires from ten to twelve mules to convey the ore from the face to the shaft bottom. The stable is underground and the mules appear to be well taken care of, as they are slick, fat and otherwise in apparent good order."

Leadington Lead Company

In 1894 the MSMI reported: "[Leadington] is one of the new companies ... and for the first time reports a product from its mine. This company was first known as the "Farmington Prospecting and Mining Company," but in January, 1894, changed its name to that shown above ... The one shaft on the property is down to a depth of 350 feet, with cage and ladder ways. They have also a mill of 100 tons which has been running steadily since last May, and turning out a fair quantity of lead ore, their report of only, one months work showing 187 tons of clean lead ore ready for market."

Flat River Lead Company

In 1894 the MSMI reported: "The property of this company [Flat River Lead Company] embraces 1295 acres of land ... It is bounded on three sides by the following well-known properties: St. Joseph Lead Company (new mines), Desloge Consolidated Lead Company and the Doe Run Lead Company. Within the past three years a great deal of money has been expended here ... A shaft has been sunk to the depth of 332 feet ... The working plant is a complete one, embracing hoisting engines, air compressor, air drills, ... reduction works with a capacity of 100 tons daily, smelter, saw mill ...."

St. Louis Smelting and Refining Company (National Lead Company)

In 1894 the MSMI reported: "The St. Louis Smelting and Refining Co. [National Lead Company] ... has purchased what is known as the Taylor property, and has erected and equipped a plant that has not an equal in the world ... Following is a description of this plant: One of the most complete and interesting power and lighting installations in the United States has been built by this company. There are a great many coal and copper mines operated by electricity, but this is the first lead mine that is so equipped ... The ore is brought up to the surface in cars holding one ton each ... and dumped on the grizzly bars, where the smaller pieces fall into a bin underneath; the larger pieces are fed into crushers ... When running at full capacity each hoist and crusher takes care of 600 tons of ore per day. When the ore is crushed it drops into a bin, underneath which travels a belt conveyor connecting with the bins in the main concentrating mill. The ore from other mines is all brought to this bin, which is the central storage supply for the mill; it is then fed into crushing rolls from these bins which break it into pieces about one-eighth inch by one-quarter inch at the rate of 1,000 tons per day. This crushed ore goes to the jigs, which separate the lead from the rock ... which is called "chats." The lead concentrates are about 70 per cent lead and go from this mill to the roasting furnaces and then to the smelter and refiners."

In 1902 the MSMI reported: "The plant was completed July, 1901 and eclipsed all other plants of this kind in the State, due to its size, the character of its construction and its splendid equipment. ... The mill ... is divided into four sections ... with a capacity of 1,200 tons. There are 176 jigs under the same roof; they are of special design, two compartment ... Considerable additions and improvements have been made during the year, the most important of which was the sinking of No. 4 shaft ... The old Taylor shaft has also been enlarged during the year ... The intention is to make of this a hoisting plant, as the mill, with its capacity of 1,600 tons, has never been run to its capacity ... The changes in the mill consist of the substitution of forty-eight Overstrom tables instead of the twelve double deck tables heretofore in use. ... There being no smelter at these mines the ore or concentrates, as they are commonly called, is shipped to the National Lead Company at St. Louis and the Federal Lead Company at Alton, Illinois."

In 1903 the MSMI reported: "Switches connect the several shafts with the mill and the mill with M. R. & B. T. ... In this mill under one roof 176 jigs are operated ... crushed material after passing through the rolls is delivered to 176 jigs, the very fine ore being passed to forty Overstrom tables ... all of the larger material having values in it is again returned to the rolls for regrinding ...."

Columbia Lead Company Commercial Lead Company

Regarding Columbia Lead Company, in 1902 the MSMI reported: "Two mines were operated during the year, with an output of 10,000,000 pounds of lead concentrates ... This property was not operated until 1900 ... The shafts are 305 and 506 feet deep ... At shaft No. 1 the equipment embraces a 250-ton mill, four steam boilers, ... twenty- six steam jigs, six Wilfley tables, steam hoister ... Columbia Lead Company has leased its land and plant for a period of ten years ... to the Commercial Lead Company ... The Commercial Lead Company is required to operate the plant to its fullest capacity and to sink another shaft on the tract just east of the St. Louis Smelting & Refining Company's mill this current year."

Regarding Commercial Lead Company, in 1903 the MSMI reported: "The Commercial Lead Company since June 13, 1903, has been in charge of the land and plant formerly known as the Columbia Lead Company ... Two shafts 287 and 480 feet deep, respectively, opened ore bodies which were worked during the year. The third shaft was started during the year ... The company owns and operates a most complete plant furnished with every facility for doing a large business. Mill has a capacity of 250 tons, with other equipment consisting of six boilers ... twenty-six steam jigs."

Federal Lead Company

In 1902 the MSMI reported: "This company [Federal] owns 500 acres of land in the Flat River district, ... One shaft was operated during the year, through which there was hoisted from its mines 8,638,365 pounds of lead concentrates ... During the last two years we have persistently endeavored to secure a description of the mill and equipment on this property. Over one year ago it was claimed that many new departures had been made from the old methods ... still we have hope, provided, the machinery embraced in these new departures does not wear out in the effort to develop the feasibility of the departure, that some sweet day we may have the pleasure of describing this wonderful mill for the benefit of other mill owners ... During the year shaft No. 2 has been sunk to the 418-foot level. This shaft is located 1,000 feet east of Flat River and 1,900 feet west of the mill and shaft No. 1. ... When the railroad switch is completed the ore will be transported to the mill in large cars."

In 1903 the MSMI reported: "ore from the Derby mine (distance about two miles) is brought by rail and discharged into flat bottom bins ... From here it is delivered to the crushers ... The ore flows down a chute, after crushing, passing under a magnet ... and then into a revolving screen ... [openings in] this screen are one and one-half inches in diameter. The screenings pass to a ... conveyor belt ... oversize passes into four No. 3 Gates crushers, is recrushed and discharged onto the same [undersize] conveyor [which] passes up an incline ... to the mill ... The ore ... is fed ... to five sets of 36x16 rolls [and] ... raised by elevator to a 4-mm screen ... the screenings pass to two 2-mm screens ... the oversize returns to the rolls. The screenings from the 2-mm screens goes into a three cone hygrometric conical sizer, thence to Wilfley tables, the oversize to jigs, ten in number. The middlings pass to the lower floor and are raised by an elevator for further treatment. The concentrates pass to settling boxes and are raised by an elevator to concentrates room ready for shipment. The fines from these are further settled ... The tailings are carried off in waste launders to creek ... At present two mines are in operation ... The equipment embraces one concentrating plant, 12 steam boilers 6 steam pumps, 4 air compressors, 3 steam hoisters and 5 crushers ... The mines in 1903 produced 11,860,320 pounds of lead concentrates ... When the plant at Federal No. 1 is completed its capacity will be about 1,200 tons per day."

In 1904 the MSMI reported: "During the year the one large concentrating plant performed all work required by the three mines in operation. The three shafts leading to the mines have depths of 338, 391 and 407 feet. Seven boilers, fifteen pumps, two air compressors, three electric hoisters, six crushers and one hundred and seventy six jigs embrace the machinery in use. The output of the mines amounted to 31,022,000 pounds of lead ore."

Hoffman (St. Joe)

In 1904 the MSMI reported: "The new mill built by the St. Joseph Lead Company during the years 1903-1904 is located at Owl Creek, about 4 1/2 miles west of Flat River. It has a capacity of about 1200 tons per 24 hours, and the mill proper is divided into 4 sections of 300 tons capacity each ... At present only the ore from two shafts is treated, viz.: the ore from Hunt shaft, which is hauled to it in railroad cars, and the ore from Hoffman shaft, which is delivered to it direct from the mine cars ... The plant as a whole is divided into three separate buildings: (i) power house, including engine room, condenser and boiler room; (2) crusher house; and (3) mill ... The crusher house is built close up to the Hoffman shaft building, and the ore from the outlying shafts (at present only Hunt shaft), is hauled by railroad cars and dumped into a storage bin ... [prior to] delivery to crushers ... which break same to 1 1/4 inch size or less ... In the arrangement of the Mill ... The unit system has been adopted. The mill, as a whole, is first divided into two main parts, which can be run entirely separate from each other. Each main part is again divided into two equal sections or units, each of which has a capacity Of 300 tons. The operation of each unit is independent of the other ... Following the ore through the mill ... we find that it is discharged at the bottom of the main mill ore bin ... into a ... bucket elevator, which carries it to the first set of sizing trammels, having 9 mm perforations. The rejections (9 mm and over) fall back to the lower floor unto a set of high speed crushing rolls, are broken up finer and returned to the first set of trammels for further classification. The troughs of the above trammels pass into a second set of trammels with 5 mm perforations. These take rejections of 5 to 9 mm which are sent to six sets of two compartment jigs and troughs, which pass to a third set of trammels having 2 1/2 mm perforations. These give rejections 2 1/2 mm to 5 mm which pass it to six sets of three compartment jigs, and troughs (below 2 1/2 mm), which first pass into a hydraulic sand classifier. This takes out all the material below 2 1/2 mm which is treated on six two compartment jigs. The fines below 1 mm undergo a careful classification in a system of hydraulic classifiers, before they go to the Wilfley tables, of which eleven are operated in each section. As most of the value in the ore is recovered by the jig process, the table feed is light, the tables receiving only 20 per cent of the ore put through the mill. This is due partly to the screening of the crushed ore, which comes from the crusher plant, prior to the second crushing in the rolls, partly to the recovery of a large per cent of coarse concentrated in the 5 to 9 mm jigs. All middlings resulting from the jigs are recrushed by middling rolls and returned to the 5 mm trommel. The jig tailings are discharged onto a-24-inch belt conveyor, which runs below the jig floor, and carried into a 600- ton tailing tank, out of which they are loaded into railroad cars to serve either as railroad ballast or concrete material. The concentrated products of the entire mill are handled by a system of conveyors, by means of which they are delivered direct into the railroad cars, ready for shipment to the smelter. The water used in the mill is pumped from Big river. Altogether about 6,000 gallons of water is used per minute."

Doe Run Lead Company - Doe Run and Elvins

In 1887 the MSMI reported: "Location of [Doe Run] plant, northwest 1/4 of section 16, township 35, range 5 east; size of dressing works, 1OOx72 feet; three 18 flue steel boilers; 12 double jigs; 2 Blake crushers; 1 incline and 1 vertical shaft; number of employees, 145, will soon employ 200; capacity, 300 pigs of lead, average weight, 80 pounds each, per day ..."

In 1902 the MSMI reported: "This company [Doe Run] owns 4,000 acres of land, ... it operated three mines during the year, with an output Of 34,060,000 pounds of lead ore ... There are three shafts on the property and all being worked; they have depths of 40, 400 and 425 feet ... Doe Run, from which the company gets its name, is a mining camp containing about 1,200 inhabitants, and located at the terminus of Mississippi River Bonne Terre Railroad. At this point the company has its extensive reduction works. At one time the company operated a refinery, but since the completion of the railroad to this point, the roasted ore has been shipped to Herculaneum ... at which point the extensive smelting works of the St. Joseph Lead Company is located ... The company was organized nineteen years ago ... It optioned at that time a portion of its present land holdings from Mr. Wm. R. Taylor ... After the Doe Run Company had drilled here for six or eight months ... it purchased the property ... A shaft was sunk, a very extensive mill erected, together with a number of calcine furnaces and a refinery. The mining, roasting and smelting of ores was carried on here until the railroad reached the place. In the meantime the company optioned a large body of land in the very heart of the Flat River district ... The first property drilled was owned by King Williams ... [Doe Run] then moved to what has long been known as the Crawley tract; thence to the Walton tract, on which, after about a year of prospecting, it decided to sink a shaft to the 400-foot level ... The shaft was started, but on reaching the ninety-foot level a water channel was encountered ... this attempt was abandoned and another shaft started about 1,000 feet distant. After the lapse of another year, No. 2 shaft was started at a point nearly a mile up river from the other shafts ... Following this another year found it sinking shaft No. 3 ... Following this, shaft No. 4 was started. This was another deep shaft and located some 400 feet from No. 1. It reached a depth of 400 feet and development of the mine commenced ... a few car-loads of very fine ore had been shipped to Doe Run, when ... another water channel was struck ..."

In 1909 the MSMI reported: "Doe Run ... owns and controls 6,548 acres of land ... The mining operations of this company are carried on through seven shafts; Nos. 1 and 4 are at Flat River; Nos. 2 and 3 at Central, about one-forth mile west of Flat River; Nos. 9 and 10 at Esther, two miles east of Flat river; No. 6 at Elvins, one mile south; and No. 8 at Mitchell ... [Doe Run] made an investment of $614,870 during 1909 for construction on plants and improvements. Among the improvements made, the new 2,000-ton mill at Elvins is worthy of special mention ... The new Elvins plant ... has a capacity of 2,000 tons per day and is built in four units of 500 tons each. Any one or all of the units may be operated as required. The building is constructed of steel throughout, with corrugated iron siding. All the floors are reinforced concrete ... The size of the building is as follows: Crusher floor, 88 x 144 feet; jig floor, 45 x 144 feet; table floor, 48 x 208 feet. The entire width of the building is 181 feet and the total area is approximately one acre. The steel ore bin is 20 x 144 feet, and is 19 feet deep; with a standard gauge railroad track on top

... All the water for the new mill is pumped from a reservoir in Flat River ... Just above the mill is a large reservoir 150 feet square, 12 feet deep, built in the clay soil on a limestone bedrock, from which the water runs by gravity to the mill. A large percentage of the water from the mill, after passing through the dewatering screen, goes to a settling pond from which it is pumped to the above reservoir ... One special feature of the mill is that the crushing is done dry. No water is added until after the ore passes the second set of rolls, where the water and ore both enter the third set of trammels. These trammels are 3 x 10 feet with 3-mm screens. The fine material from this trommel passes through a Richards classifier from which fines go to the Wilfley tables independent of the Hancock jig. The removal of all the fines at this point is another feature of this mill. The 3-mm sand is sent to Harz jig while the coarse material from 3 to 9-mm is treated on a Hancock jig. The Hancock jig produces heads from two cells, middlings from two and tailings from one. The Harz jig produces heads from the first two cells, middlings from the second and tailings from the overflow. The middlings from the Hancock jig pass through a 3-mm trommel from which the oversize goes to a pair of 14 x 30 inch rolls and by bucket elevator to the trommel in front of the jigs. All the 3-mm size goes through a Huntington mill to a dewaterer. The spigot producer is drawn off to the elevator and goes back to the trammels in front of the Hancock jig. The overflow passes to a 6-foot V-shaped settling box, from which the overflow goes to the fine pond, and the spigot product to a Frue vanner. In this way all the middlings are crushed to pass a 3-mm screen and then enter the Harz jig and fine treatment system. Just in front of the Harz jig are two 20-inch Richards vortex classifiers, the overflow from which passes to two dewatering boxes; the spigot product passes to the Harz jigs. The spigot product from the dewatering boxes, goes to two Richards annular classifiers which produce three products distributed on Wilfley tables. The overflow from the dewatering boxes passes to two V-shaped settling tanks, the spigot product from which goes to Wilfley tables and the overflow to the fine pond."

Desloge Consolidated Lead Company

In 1902 the MSMI reported: "The company [Desloge] at present has in use four large boilers, eight pumps ... seven crushers and fifty-six steam jigs ... The concentrating plant has a present capacity of 600 tons per day, but it is to be increased to 800 tons. ... The mill is equipped with twenty-seven Klein double-acting ore jigs; eight Klein combination classifiers; seven Klein pneumatic tables, to be increased to eighteen shortly; three pair each of Milwaukee and Chicago rolls; three Blake crushers; two Chillian and one Bryant mill for regrinding."

2.4.2 St. Joe Mining and Milling Practices - 1947

During 1947, St. Joe described its mine and mill operations at its southeast Missouri Old Lead Belt complex. That article is summarized here as being representative and descriptive of operations and practices during the peak production years in the Old Lead Belt mining district.

Mining Practices

Drifts were typically 10 feet wide and either 8 or 9 feet high. Normally the cycle of operations in drifting was performed by a two-man crew, a motor operator and a shovel operator who first load out the rock broken by the preceding shift. All drilling was wet.

Blast holes were generally drilled 8 feet deep and square-up holes 6 to 7 feet deep. After drilling, the crew would load the drill rigs in the shovel dipper and take the shovel a safe distance back from the face. They then charged their holes and fired them near the end of the shift. Blasting was done electrically using instants in the cut holes and five delays. About 15 pounds of 7/8 inch by 8 inch powder was used per foot of drift advance. The average length of the drift round broken was approximately 5 feet.

Most drifts were driven on a two shift basis, with four hours elapsing after blasting before the next shift came in. A few long drifts, with special ventilating arrangements, were driven on a three-shift basis. Approximately 68,000 feet of drift and raise were driven in the district during 1946. Generally, "equivalent drift footage" (which includes ditching and side slabbing, driven by the development crews) amounted to approximately double the total footage of regular drifts and raises.

Mining progressed by the room-and-pillar method leaving open stopes. No timbering or filling was used. The heights of the stopes varied. Loading equipment, however, required a minimum of 7 1/2 feet. Stopes were mined as high as 240 feet. The average height of stopes was approximately 10 feet. Pillars were generally circular and the distance between them depended on the type of ground. A minimum of 19 feet was required for a St. Joe shovel to swing, so in shovel stopes this was the minimum distance possible between pillars. Pillars were spaced as far apart as roof conditions would allow, generally 25 to 30 feet measured between perimeters. The size of pillars varied from about 15-foot diameters in low ground to as high as 50-foot diameters in high ground. In some stopes with bad back conditions the back was supported by means of 4-inch channel irons held in place by 1-inch wedge bolts driven into the back.

Breast stoping was used in ground up to 10 feet high. In higher ground the breast was advanced ahead of the bluff, and the bluff was later shot by means of lifters or, if necessary, lifters and splitters, or sometimes by means of vertical stope holes.

Side slabbing was the standard method of breaking rock in the breasts of the stopes. Three hole settings, consisting of single or double settings, were generally drilled so that the center hole would have about 6 inches less burden on it than the top and bottom holes. The average amount of ore broken in the stopes per drillman shift was 52 tons. In this district all the ore and development rock was loaded mechanically.

Transporting the ore from the working faces to the hoisting shafts was the most expensive single operation underground. The installation and maintenance of the several hundred miles of track, trolley wire, and feeder cable necessary in a haulage system, where the average length of haul was approximately two miles, was in a large measure responsible for this fact. In the early days, in numerous shafts in the district, the ore was hoisted to the surface and then transported in railroad cars to the nearest mill. This made the underground hauls comparatively short, which was certainly an advantage, since the hauling was done entirely by mules pulling 1-ton cars. However, with the introduction of trolley locomotives and larger capacity cars, it became more economical to haul to a centrally located shaft where the ore was hoisted directly at the null. Adherence to this procedure resulted in increasingly long hauls as the mines spread out.

Locomotives, ranging in size from 2.5 to 4.5 tons, were used in pulling the ore trains. Most of the mainline locomotives were 15-ton with 90-hp motors. Smaller locomotives were used for gathering in the headings and were equipped with reels holding 600 feet of No. 2 rubber-covered conductor cable.

The mainline haulage tracks in each mine were divided into blocks, and a system of red and green signal lights was installed at the end of each block to prevent more than one locomotive from operating within the block at one time. These signal lights were hand operated but proved satisfactory from a safety standpoint. At one mine, where the amount of haulage was large, automatic block signals were used in the area near the main hoisting shaft.

Standard mine cars had a capacity of 48 cubic feet and hold an average load of 5,400 pounds of ore. The swivel couplings were designed so that it was not necessary to uncouple the cars in the rotary dumps. One mine used a smaller 2-ton capacity car with rigid couplings, but the ore was hoisted in the cars and was not dumped in an underground ore pocket. Newly designed cars of 13-ton capacity were used at one mine and proved more efficient, both for loading and hauling, than the 48-cubic-foot car.

Hoisting of ore from the various mining units was concentrated at four shafts but there were 10 other shafts where men, materials, supplies, and waste rock were hoisted. Equipment at these shafts varied owing to the date installed. The vertical distance that ore was hoisted ranged from 322 to 544 feet. Other shafts varied in depth from 360 to 688 feet.

Approximately 20,000 gallons per minute (gpm) of water were pumped to the surface from the mines in St. Francois County at heads varying from 320 to 497 feet and averaging 465 feet.

Milling Practices

During 1947 St. Joe operated four mills in the Missouri Old Lead Belt having a total rated capacity of 24,300 tons per day and divided as follows: Federal, 12000 tons; Leadwood, 4800 tons; Desloge, 3600 tons; and Bonne Terre, 2400 tons. The four concentrators were similar in a general way, differing mainly in size and type of equipment.

A simplified flow diagram of the Bonne Terre mill operations is shown in Figure 2-10.

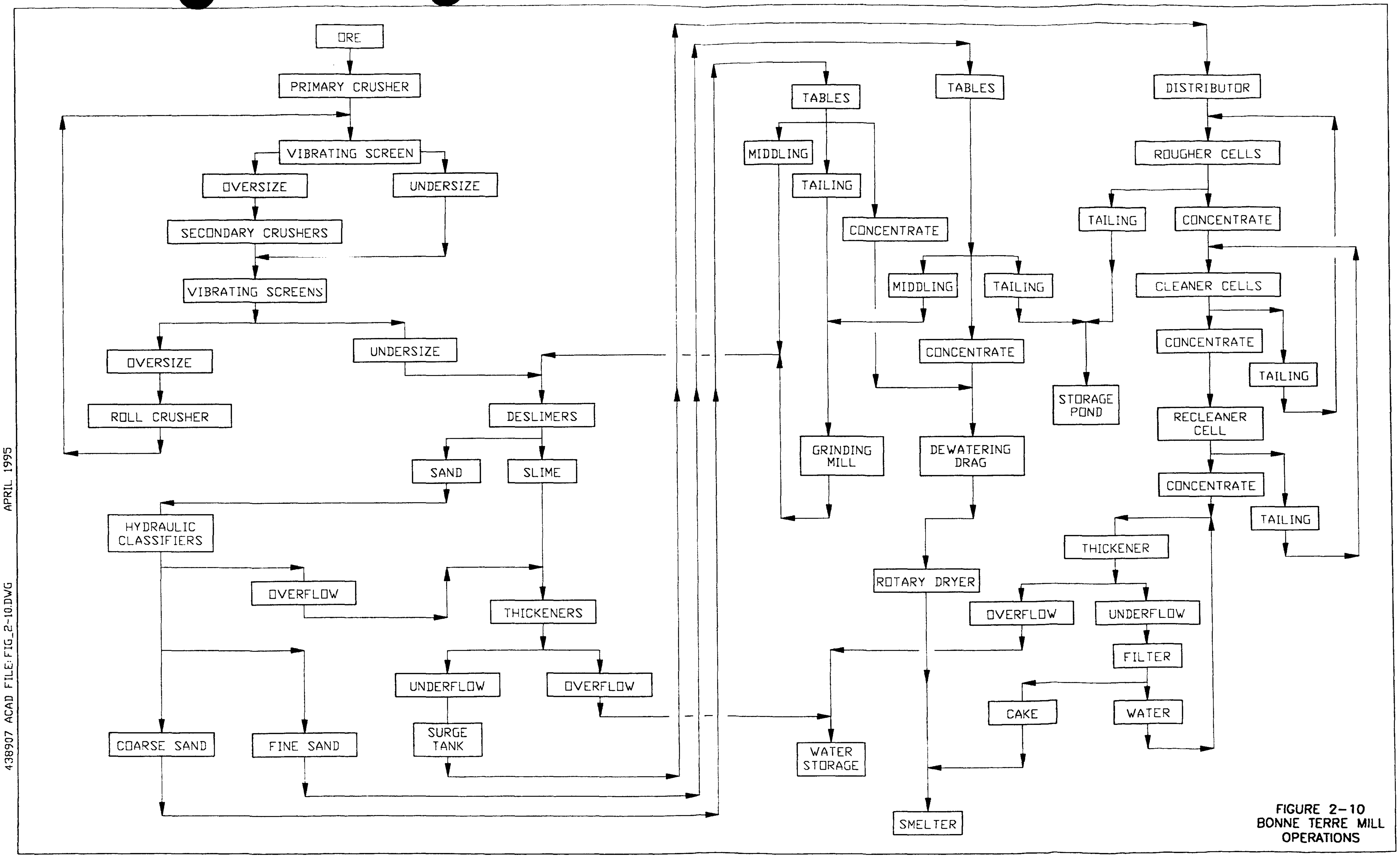


FIGURE 2-10
BONNE TERRE MILL
OPERATIONS

438907 ACAD FILE:FIG_2-10.DWG APRIL 1995

According to St. Joe, no attempt was made to rigidly standardize procedures in the various mills in spite of a general variety in the ores being mined. In the paragraphs below a generalized description of the milling process is given, noting important differences in procedures at the various plants.

The concentration process may be divided into five main stages: 1) dry crashing, 2) wet grinding, 3) desliming and classification, 4) tabling, and 5) flotation. All ore was hoisted at shafts adjacent to crushing plants, eliminating surface transportation of ore. Telsmith crushers were used for primary crushing at all the mills. A rough elimination of fines in the feed to these crushers was made using either stationary or revolving grizzlies.

The crusher product was conveyed to grizzlies of the stationary-bar or vibrating-screen type. Here a separation at about one inch was made, the oversee going to secondary crushers. Secondary-crusher discharge joined the grizzly undersize and was conveyed either to storage bins or directly to screening plants. All mills had storage bins of varying capacities either preceding or following dry screening. Ore was weighed at some point in the dry crushing system.

Secondary-crusher product was screened dry on vibrating screens using wire cloth with an 0.08 by 0.10 inch opening. Oversize from dry screening was reduced by roll crushers. Several makes of the standard belted type were used. The Bonne Terre mill used two 54-by-24-inch Traylors; the Leadwood mill, four 36-by-15 inch Allis-Chalmers; the Desloge mill, two 64-by-26 inch Buchanans and one 36-by-15 inch Allis-Chalmers; and the Federal mill, six 48-by-24 inch Traylors. Except for the larger rolls at the Desloge mill, all rolls were driven with one belt. In general these crushers produced a product containing about 50 percent minus 1/2 inch and 5 percent plus 1 inch. Roll product was conveyed back to the dry screens, forming a closed circuit. Circulating loads in this circuit were large, being from four to six times the original feed rate. Practice was to accomplish a large part of the necessary reduction with rolls rather than by wet grinding. This practice seemed to produce a minimum of fine material thus permitting a large part of the mineral to be recovered by gravity concentration rather than by the more expensive flotation process.

By carrying crusher-roll reduction to a point at which 85 to 90 percent of the product passed 14 mesh, the greater portion of the galena was liberated.

After mechanical sampling, the screen undersize was defined in cones usually 7 feet in diameter at the top. A central feed distributor with a baffled bottom broke the force of the incoming feed stream. A bottom chamber introduced clear water and contained a spigot for continuous sand discharge. Fine overflowed into a launder around the upper edge of the cone. The spigot discharge was a mixture of various-sized sands which were classified before being tabled.

The overflows of the definers and classifiers were laundered to thickeners. Classifiers varied in size depending upon the tonnage handled and the number of tables to be fed. A common arrangement was to have 24 to 30 cells arranged in two rows of 12 to 15 cells each. By careful attention to spigot size and amount of hydraulic water a well graded series of sands was produced which constituted the feed to the tables.

Various types of head motions, including Deister, Butchart, Wilfley, and a locally designed motion, were used. Rubber covers and riffles were used exclusively. Three products were made on the tables: a finished concentrate assaying 75 to 80 percent lead; a middling that was recirculated through the classifiers if much free mineral was present or ground in mills if the free mineral content was low; and a tailing that was either re-ground or sent to waste. The tables handling the coarsest sand from the classifier made a middling that contained considerable free mineral at times and, as mentioned, was returned to the classifiers.

Tailing from the coarser tables was sent to mills for regrinding. The finer tables made a middling that was reground and a tailing carrying 0.08 to 0.10 percent lead that was sent to waste. The classifier-table circuit was a system that could be and was varied to meet different conditions. The table tailing was reground to a point in which the extra mineral freed paid for the expense of treatment.

Table concentrate was handled by two methods. At Bonne Terre the concentrate was dewatered in an drag classifier to 15 percent moisture and dried in a 2-by-8 foot rotary gas-fired dryer. At the other mills, concentrates were pumped to storage cones from which a thickened spigot product was sent to 8-by-2 foot filters.

Dried or filtered table concentrate contained 2.5 to 3.5 percent moisture. Several types and sizes of grinding mills were in use: Leadwood and Bonne Terre mills used 6-by-4 foot Allis-Chalmers ball mills converted to rod mills; Federal mill used 6-by-12 foot Allis-Chalmers rod mills; and the Desloge mill used 4-by-10 foot Allis-Chalmers rod mills charged with 2-inch balls. All mills were of the open-trunnion-discharge type and were lined with manganese steel. The feed to the mills, consisting of the table rejects, was usually not dewatered but was laundered directly to a feed-box at the mill, where it was introduced into the mill through a pipe feeder. The pulp density was quite low, ranging from 30 to 40 percent solids. The consequent rapid passage of the large volume of feed through the mill resulted in a minimum production of fines. This grinding of a dilute pulp, besides producing the desired results, eliminated dewatering. Launders carried fines from definers to thickeners ranging in size from 40 to 200 feet. The 30 to 35 percent solids thickener spigot product constituted flotation feed.

Flotation cells were approximately 3 feet wide, 2 1/2 feet deep and 36 feet long for roughing and 12 feet long for cleaning. The machines were built in units of one rougher and one cleaner. The rougher cells made a finished tailing of 0.08 to 0.10 percent lead. The cleaner float, assaying approximately 15 to 20 percent lead, was stepped up to 65 to 70 percent lead by one or two recleanings in separate cells. Cleaner cell middling was returned to the original or rougher feed giving a circulating feed of 16 to 24 percent solids.

Reagents used were a mixture of hardwood creosote and Sharples Pentaftl frother 124-E as a frothing agent, and Bear Brand L9 or American Cyanamide Aerofloat 343 as a collector. Two of the mills found Aerofloat 31 the most satisfactory collector. Sodium cyanide was used as a depressant for pyrite. Although no pieces of identifiable oxidized minerals had been found, surface oxidation of galena was suspected on some ore and the Bonne Terre and Desloge mills found the use of sodium sulfide highly beneficial at times.

The approximate amounts of reagents used per ton of flotation feed were: creosote and Pentasol frother, 0.15 to 0.25 pounds; Z-9 or Aerofloat 343, 0.03 to 0.05 pounds; cyanide, 0.007 to 0.01 pounds; and sodium sulfide, 0.10 to 0.30 pounds.

An average of 60 percent of all ore tonnage was treated by flotation. However, only about 40 percent of the total concentrate was flotation concentrate, as considerable fine galena was recovered on the tables leaving an impoverished feed for flotation treatment.

Flotation operations in the district were standardized perhaps more than other concentration operation. The Desloge mill varied the usual practice by treating in a separate plant the fine produced by dry crushing. Experiments proved that this primary fine at Desloge was much less responsive to flotation than fine produced by wet grinding, so this primary fine was sulphidized with sodium sulfide and treated separately.

Final flotation concentrate was settled in thickeners. The thickener underflow, containing 65 to 75 percent solids, was filtered. The cake containing about 15 percent moisture was dried in natural gas fired rotary driers.

Table tailing was dewatered either in classifiers, drags, or definers. The overflow from these various devices contained some small lead values and was sent to thickeners or used as feed water in launders.

The dewatered and defined table tailing was usually combined with the flotation tailing and pumped to storage ponds. A large amount of this combined tailing, and also of table tailings alone, was sold for agricultural limestone.

In contrast with most operations in the district, underground haulage was entirely trackless, and nearly complete delineation of the large, well defined ore body by drilling permitted comprehensive planning of development and mining in advance of shaft sinking. The ore differed in character and occurrence from that of the main ore deposits in the Lead Belt in that the lead mineral, galena, occurred in the dolomitic matrix enclosing granite boulders instead of in dolomite limestone.

The Hayden Creek mine was one of the newer operations in the Lead Belt. It was also referred to as the No. 22 mine because the shaft was the 22nd to be sunk in the district by St. Joe. The ore body was discovered by random diamond drilling in 1943, but systematic drilling to outline the ore did not begin until 1948. Shaft sinking began in May 1949 and underground development in July 1951.

The character and occurrence of the Hayden Creek ore body were unique in the Lead Belt. The ore occurred in a cemented granite boulder bed on the flank of a Precambrian granite knob (fig. 2), whereas most of the ore mined in the Lead Belt occurred in disseminated and bedding-plane deposits in the Bonne Terre dolomite.

The boulder bed consisted of two units separated in part by a tongue of sandstone. The lower unit, which had a maximum thickness of 15 feet, was a basal conglomerate that lay directly upon the granite surface. Overlying this unit was the Upper Cambrian Lamotte sandstone, which pinched out along the flanks of the granite knob. The upper, main boulder unit, extended out over the sandstone for many hundreds of feet south of the knob. This boulder mass, which had a maximum thickness of 115 feet, contained most of the ore. The Bonne Terre dolomite overlay and in some places interfinged with the main boulder unit on the flank of the knob and overlay the sandstone beyond the outer margin of the boulder bed.

The boulder bed or conglomerate consisted of unsorted granite boulders and fragments cemented by sandy dolomite. The large boulders ranged from 6 inches to several feet in diameter and were well rounded. The presence of several rudely stratified boulder zones and lenses of dolomite within the boulder bed and the interfingering of Bonne Terre dolomite with it indicated that the main boulder unit was a shoreline phase of the lower part of the Bonne Terre formation.

Galena, the only ore mineral, mainly occurred as disseminated grains replacing the cementing dolomite and to a minor extent as fracture filling in granite boulders. Not all of the boulder bed was mineralized; the largest continuous ore zone lay just above the top of the Lamotte sandstone in the lower part of the main boulder unit and west of the sandstone pinchout. Other smaller, less continuous ore zones occur higher in the boulder bed, and some drill holes showed considerable thicknesses of low grade material between the upper ore zones and the main ore body. A small quantity of ore was found in the basal conglomerate near the sandstone pinchout.

The Hayden Creek ore deposit was about 1,600 feet long and 400 feet wide and ranged in thickness from 9 to 80 feet. The long axis was north-south and the floor of the main body of ore sloped upward to the north at an average gradient of 2.5 percent. In the west-central part of the mine a small but minable ore body occurred about 50 feet above the haulage level.

Access to the mine was through a vertical shaft sunk in the country rock 40 feet from the west edge of the ore body. The ore pocket and underground crusher room were cut in the rock between the shaft and the ore body. Development drifts, 9 by 12 feet in cross section, were driven into the ore from the shaft station. Only one haulage level was cut. The upper, smaller ore body was developed by driving two inclined raises from the haulage level to the ore. After a connection had been made between the raises on the upper mining level, one raise was used as an ore pass and the other for access of men, equipment, and supplies.

Underground development, which included excavation of a crusher room and the shop and supply rooms, was begun in July 1951. Mining was begun on a small scale in July 1952. The rate of output had increased to 1,000 tons of ore per day by June 1953 and averaged 1,303 tons per day during the last 6 months of that year. Production was cut back in October 1954 to a daily average of 1,000 tons and was maintained subsequently at that rate. All mining was done on a two-shift schedule.

The room-and-pillar method was adopted for mining the Hayden Creek ore body. The rooms, which were 26 feet wide between 20-foot pillars, were driven along lines set by the surveying crew. Rooms were advanced upgrade along the floor of the ore body, and pillars were turned by crosscutting at specified intervals. Mining was initially limited to a height of 9 feet, regardless of the thickness of ore. This restriction was imposed because: 1) the reaction of the boulder conglomerate to mining was unknown at the time and limiting the height of openings to 9 feet permitted close checking of the back and side walls and 2) cost data for the V-cut stope round method of breaking ore were desired for comparison with costs for the side-slabbing method that was commonly used in the Lead Belt. The restriction of room height to 9 feet was continued until February 1953 when the limit was raised to 10 feet. This limitation was removed later in the year, and headings were driven thereafter up to 14 feet in height.

All drilling, during the period when mining was confined to advancing the room headings, was done with mobile, rubber-tired drill jumbos. The jumbos were operated by air motors and were equipped with two hydraulic boom arms. A standard V-cut jumbo stope round of 36 holes was drilled for breaking ore in the headings. The rounds were pattern drilled, and the various positions of the boom arms were marked to eliminate guesswork in directing the holes. Ore breaking with the jumbo round averaged 76.7 tons per drill shift in the second half of 1953.

"Back slabbing," a term used in the Lead Belt to denote the method of mining ore from the backs of stopes or rooms, began in January 1954. Nearly 44 percent of the ore produced from then to October 1, 1955, was mined by this method. At Hayden Creek drill jumbos and column-mounted drills were used for back slabbing. With both types of equipment, rounds of upholes were drilled first and blasted; then the machines were set on top of the broken ore, and slabbing continued to the limits of the ore.

Semi-gelatin dynamite of 45-percent strength was used for ore breaking. Millisecond delay blasting caps with 12-foot lead wires were connected in a single series and fired by a blasting machine. The holes were loaded and blasted by the driller as part of the work of his shift.

No support other than the pillars was required for stopes within the boulder conglomerate. The backs and walls of the haulageways and active headings were checked periodically and all loose rock, regardless of size, was barred down. Most of the loose material was small. In drifts and rooms where the back was dolomite, unstable roofs were supported by 4-inch channel irons pinned by 1-inch roof bolts. Lengths of bolts varied according to thickness of the unsound strata, but 10 feet was the length most commonly used. This method of roof bolting was in general use throughout the Lead Belt.

All ore produced in the Hayden Creek mine was loaded for underground transport with electrically operated Joy loaders. Alternating current was transmitted at 440 volts to the headings, where transformers converted it to 220 volts for operation of the loaders. Loading performance averaged 237 tons of ore per machine shift in the second half of 1953 and 286 tons in the first 9 months of 1955.

The ore mined on the upper level was moved by scraper hoists to the ore pass, where it fell to the haulage level below. The scrapers were the same as those used in the early stages of development.

Rock and ore were transported underground entirely by trackless equipment. Electric shuttle cars were used initially but were supplemented by diesel-powered trucks in 1953. After 1953, the major part of the ore moved from the stopes to the underground crushing plant was hauled by diesel trucks.

Underground haulage roads were constructed of crushed stone and were graded periodically by dozer. Well-maintained drainage ditches keep the road beds dry.

Ore was dumped from shuttle cars and trucks onto a 30-inch chain drag conveyer and was elevated thereby to a crusher. The crushed ore dropped to a 30-inch belt conveyer and was moved to the skip pocket.

2.4.3 Descriptions of Technologies Used

Process technologies identified in Section 2.4.2 and elsewhere include mining (room and pillar, typically), beneficiation (flotation and gravity, including jigs and tables) and smelting (ore hearths and reverberatory furnaces).

An ore is defined as a naturally occurring aggregate of minerals from which a metal may be extracted at a profit. The phrase "at a profit" is the factor that determines whether or not a given deposit is an ore or a worthless rock. Hard-rock ore is rock, i.e., an aggregate of minerals. A mineral is defined as a naturally occurring homogeneous inorganic substance of definite chemical composition and with certain characteristic physical properties. The ore minerals are those minerals that contain the valuable metals in an ore. Ore minerals may be native metals or chemical compounds of the metals.

The most common nonferrous ore minerals are sulfides, and ores containing them are known as sulfide ores. The valueless minerals found in ores are the gangue minerals which together with roof and wall rock broken with ore are called wastes. The dividing line between ore minerals and gangue minerals is fixed by the "profit phrase" in the definition of an ore.

Ore Dressing

The first process most ores undergo after they leave the mine is ore dressing, also called ore preparation, milling, mineral dressing, or beneficiation. Ore dressing is a process of mechanically separating the grains of ore minerals from the gangue minerals to produce an enriched portion of concentrate containing most of the ore minerals and a discard or tailing containing the bulk of the gangue minerals. The fact that most ore minerals are usually finely disseminated and intimately associated with gangue minerals means that the various minerals must be broken apart or liberated before they can be collected in separate products. This liberation is accomplished by comminution, or crushing and grinding of the ore. After the ore has been ground to the proper size, it is subjected to some process of concentration which separates the mixture of mineral grains into two or more products.

Comminution and concentration are the two primary operations in ore dressing, but many other important steps are involved including: sizing and classifying mineral mixtures, and thickening, dewatering and filtering ore-water pulps.

With the exception of some magnetic and high-tension separators and hand-picking operations, all the common concentrating devices act upon a mineral-water pulp. Crushing and grinding liberate the mineral particles while screening and classification put the pulp in the condition best suited for a particular concentration process.

The separation of mineral mixtures into two or more products is possible because of differences in various properties of the minerals. The difference in color and luster is used in hand picking; difference in density permits separation by various methods of gravity concentration; differences in magnetic properties permit the use of magnetic separation; and the differences in surface properties of minerals account for the separations made by the froth-flotation process.

Gravity Concentration

Before the advent of the flotation process, gravity-concentration methods were the most important of all concentrating processes. Gravity methods operate by virtue of the differences in density of various minerals; the greater the difference in density between two minerals, the more easily they can be separated by gravity methods. Gravity concentration methods used in the Old Lead belt included jigging and tabling. These technologies are reviewed below.

Jigs. Jigs are gravity concentrators designed for handling material that is too coarse for table feed (1 to 5 inches in diameter down to 2 millimeters). A jig consists essentially of a screen which supports a bed of ore (under water) and is provided with means of bringing the ore bed into partial suspension at regularly recurrent intervals. This may be accomplished by suddenly dropping the screen for a short distance (movable-screen jig) or by forcing a current of water up through the screen (fixed-screen jig). After each pulsation the ore is allowed to settle back on the screen, and after a few repetitions of the pulsation-subsidence cycle, the minerals in the bed stratify with the light mineral (tailing) on top and the heavy mineral (concentrate) at the bottom. Jigs are operated by continually feeding material into the screen compartment and removing the light tailing from the top of the bed to permit the layer of concentrate to build up. After a sufficient quantity of concentrate has accumulated, it may be removed either manually or automatically. Theoretically, a jig will produce tailing and concentrate, but because of the coarse size of the material, either one of these may be really a middling which must undergo further grinding and concentration. The effective agent in a jig is the jig bed above the screen, which consists of the heavy minerals in the ore and behaves in some respects like a dense fluid. The pulsation of the water or the motion of the screen keeps the bed open or in suspension during part of the cycle so that heavy minerals entering the jig can settle into the bed. Lighter minerals cannot penetrate the jig bed, and so are forced to remain in the upper part of the jig and eventually discharge over the top. Concentrate is withdrawn near the screen at such a rate as to keep the jig bed always at the proper depth. Small, heavy minerals that penetrate the bed and are smaller than the meshes of the screen will pass down into the hutch.

Concentrating Tables. If water is allowed to flow over a flat inclined surface, it produces a flowing film, and the velocity of the water in the film varies with the depth. Close to the surface of the table the water is held back by friction against the water adsorbed on the surface, and at points in the film farther away from the surface the water has a greater velocity. This means that a very small particle will not wash down the surface so rapidly as a larger particle because it is submerged in the slow-moving portion of the film. If two particles of the same size are placed in a flowing film, the particle with the lesser density will be washed down most rapidly. Suppose now we have a slightly inclined deck with water flowing over it from top to bottom, and we introduce a mixture of minerals at the upper right-hand corner. If the table is vibrated longitudinally, using a slow forward stroke and a rapid return, the mineral particles will "crawl" along the deck parallel to the motion of the table. Any mineral particle, therefore, is subjected to two forces, and the net result is that the particle will move diagonally across the deck from the upper right-hand corner to the lower left-hand corner; since the effect of the flowing film of water depends upon the size and density of the particles, a mixture of particles will fan out on the table, and the small, heavy particles will ride "highest" on the table.

A shaking table consists of a flat deck, usually covered with linoleum and having on its surface a number of thin wooden strips or riffles. There are many different types of riffles used on shaking tables. In one of the most common arrangements the riffles are parallel to the long dimension of the table. Usually they are thickest near the feed end of the table and taper down toward the discharge end. The riffles may cover the entire table surface, or they may cover only a small portion of the surface, depending on the nature of the material being treated. As a rule, the riffles lie parallel to the direction of the motion of the table, and the water film flows across them.

The shaking action of the table causes the minerals to stratify in the spaces between the riffles in much the same way as they stratify in a gold pan. The light minerals work to the top, where they are exposed to the crosscurrent of water, and the heavy minerals settle to the bottom and travel along the table parallel to the riffles. The riffling on the surface assists in the separation of the particles and increases table capacity.

Flotation

The importance of flotation in modern ore-dressing practice results from several factors that have caused it to supplant gravity concentration. Some of the reasons for the change to flotation follow:

1. The necessity for mining and treating ores in which the ore minerals were finely disseminated required finer and finer grinding to liberate the values. The resulting fines were difficult to handle by gravity methods.

2. In many complex ores it was desirable to separate the valuable ore minerals into two or more separate concentrates to facilitate subsequent chemical treatment. Galena-sphalerite, pyrite-sphalerite, and other mineral separations were desired, but the spread of density between these minerals was so small that gravity methods were unsatisfactory. Differential flotation has solved many of the milling problems connected with complex ores.

3. The natural tendency of finely ground sulfide minerals to float on the surface of water was a hindrance to gravity operations such as tabling. This tendency was turned to good advantage in the flotation process.

4. Sulfide ores are by far the most important type of nonferrous ores, and most sulfide minerals respond readily to flotation treatment.

Regarding operation of a flotation cell, the ore-water pulp feeds into the cell and is kept agitated and in circulation by an impeller mounted at the bottom of the vertical shaft. In one type of flotation machine the rotating impeller creates vacuum enough to draw air down a standpipe surrounding the impeller shaft, and the impeller disperses the air throughout the pulp in the form of small bubbles. The floatable minerals are carried upward by the bubbles and eventually collect in the froth above the pulp in the machine. Nonflotable minerals remain in the body of the pulp, since they have no tendency to adhere to the rising bubbles. Automatic scrapers remove the mineral-laden froth which contains the concentrate, and after the values have been removed, the barren pulp containing the tailing flows out of the cell.

Flotation cells are usually operated in series, with the pulp flowing continuously from one cell to the next, giving up some floatable mineral in each cell. The size and number of cells and the rate of pulp feed are adjusted so that the last cell in the series makes a finished tailing; i.e., practically all the floatable minerals are removed from the pulp before it discharges from the last cell.

Reagents Used. Flotation processes require that mineral surfaces be acted upon by various chemical agents. Agents include frothers, collectors, activators, depressants, and conditioners. Gravity concentration techniques do not require the use of any reagents. Typical reagents used in flotation practice are reviewed below.

Frothers. If air is bubbled through water, the bubbles break up as soon as they reach the surface and do not form a stable froth. To cause a layer of froth to form on the surface of a pulp, it is necessary to add a reagent that serves to stabilize the froth and hold the minerals until the froth can be scraped off into the concentrate launder. The most common frothers are pine oil and cresylic acid. Small amounts of these substances in a pulp lower the surface tension of the liquid and cause bubbles to form a stable froth. Frothers perform only this one function. They have practically no effect on the floatability of the minerals in the pulp.

Collectors. Some minerals, such as galena, will float quite readily without the addition of any collector to the pulp. Others, such as sphalerite, ordinarily cannot be floated unless a collector is added first, which alters the mineral surface in such a way as to cause it to adhere to an air bubble. Many investigators doubt that even galena is naturally floatable if absolutely clean and unaltered at the surface; but whether a sulfide mineral has any "natural" floatability or not, the practice of using collectors is universal. The exact mechanism of the action of collectors is still obscure, but it appears to be fairly well established that if a mineral is to float it must have an air-avid surface. Clean glass has a water-avid surface and is easily wetted by water. If a drop of water is placed on a clean glass plate, it immediately spreads out and completely wets the glass surface. A drop of water placed on the surface of solid paraffin, however, remains as a coherent drop with as little surface as possible in contact with the paraffin. We say, then, that the paraffin has an air-avid or water-repellent surface; such a surface seems to prefer contact with air to contact with water, and a particle with a surface of this sort would adhere to an air bubble and float out of a flotation pulp. The object of all reagent additions in flotation is to form a water-repellent (paraffin-like) surface on the minerals to be floated, and a water-avid surface (like that of clean glass) on the minerals that are not to float.

A typical collector is sodium xanthate which, when introduced into the mineral-water pulp, dissolves and ionizes in water into Na+ ions and singly charged negative xanthate ions. When lead sulfide (PbS) is immersed in a water solution containing dissolved xanthate, insoluble lead xanthate is formed on the surface owing to attachment of xanthate ions to the lead atoms on the surface of the particle. This coating of lead xanthate is oriented so that the long hydrocarbon chains point outward, giving a water-repellent surface which is in effect the same as a paraffin surface. When such a coating has been formed, the particle is said to be oiled or treated so that it is ready to be floated.

Many other reagents have been used for collectors, although xanthates are the most common. All collector molecules (or ions), however, have the same type of structural reactive end which can attach to the mineral particle, and a water repellent end which produces the "oily" coating. Collectors of this type do not ordinarily attach themselves to gangue particles, so the gangue particles do not float.

Depressors. Depressors are those substances (usually inorganic) whose presence in the pulp prevents the anchoring of the collector molecules onto a mineral surface and thus inhibits flotation of the mineral. Activators are those reagents which have the opposite effect; they affect the surface of minerals in such a way that it is easy for the collector atoms to become attached. Differential flotation, or the removal of two or more minerals as separate concentrates, is made possible by the use of suitable depressors and activators. One of the most common applications of differential flotation is the treatment of lead-zinc ores. Sodium-cyanide is a depressant for sphalerite but not for galena, so that, if sodium-cyanide and xanthate are added to a flotation pulp, the galena floats and the sphalerite remains in the tailing. If the tailing from the lead cells is treated by the addition of copper-sulfate (an activator for zinc sulfide) in the presence of more xanthate, the zinc-sulfide becomes floatable and can be collected as a zinc concentrate substantially free from lead. Sodium-cyanide and lime are depressors for pyrite.

Conditioners. Conditioners are those substances added to the pulp to maintain the proper pH (measure of acidity or alkalinity of the pulp) to protect such salts as sodium-cyanide which would decompose in an acid circuit. Sodium-carbonate and lime are the most common conditioners, since most flotation pulps should be alkaline.

Quantities of Reagents. The amount of reagent used in flotation practice is usually very small in comparison to the amount of ore treated. Reagent consumption is commonly given as pounds of reagent per ton of ore treated, and the reagents consumed in floating typical lead-zinc ore are about as follows:

Reagent	Amount Consumed (lb per ton)
Frothers	0.1-0.2
Depressant	0.1-0.3
Activator	0.8-1.2
Conditioner	1.0-2.0
Conditioner	2.0-4.0
Collector	0.01-0.2

Flotation pulps must undergo a certain conditioning period before the froth is removed to allow the reagents to act on the mineral surfaces. Usually the pulp is agitated for 10 to 20 minutes in a conditioning tank before it enters the flotation cells.

Smelting

As previously noted, to about 1800 the lead ore mined in Missouri was entirely galena, occurring as deposits in clay. The early openings were very shallow, seldom more than 10 feet in depth. The ore, cleaned of clay by hand, was smelted either on log piles or in a crude construction known as the log furnace. A log furnace was typically built against the side of hill sloping about 45 degrees. Three large oak logs were rolled into the furnace transversely, resting on ledges at the sides. Small split logs were set tip vertically around the inside of the furnace, after which about 5,000 pounds of ore in pieces averaging 15 pounds were piled up in the furnace, covered with logs, and a fire started. Metallurgically the method of smelting would be classed as a roast-reaction process. The fire was kept low for about 12 hours, during which the roasting took place. A stronger heat was then maintained for 12 additional hours, to effect the reduction, during which period lead trickled out into a basin in front of the furnace. Sometimes the reduction period would have to be extended to 24 hours, depending largely upon the skill of the operator. The extraction of lead by this process was very imperfect. Judging from ore obtained from similar deposits, the grade of the material was likely upward of 80 percent lead or 1,600 pounds lead per ton of ore. The yield of lead from a ton of ore smelted in the log furnace was only 700 to 800 pounds or less than 50 percent of the lead in the ore. There are no records of log furnace operations in St. Francois County.

A noteworthy event in the history of lead mining in Missouri was the arrival, in 1799, of Moses Austin who introduced what was called the "ash" furnace, which was designed to supplement the log furnace. It was impossible to attain a good reaction from ore as coarse as that charged into the log furnace, and the loss of lead was largely due to its remaining unreduced in the cinders, or ashes, left in the furnace. Austin crushed these ashes moderately fine and charged them into the ash furnace, which was a crude reverberatory with a sloping hearth, where they were heated about two hours, extending the reaction left incomplete in the log furnace. In this way, an additional extraction of about 15 percent was effected. The furnace was built of limestone and lasted only 15 to 20 days of continuous work, but in view of its low initial cost this was not a serious matter. At the time of Austin's arrival, there were about 20 log furnaces in operation near Potosi. They could not successfully compete with a smelter who could extract 15 percent more metal from the same ore, and in 1802 only one of the old furnaces was running. As with the log furnace, there are no records of operation of ash furnaces in St. Francois County.

Two smelting technologies which are known to have been practiced in St. Francois County from about 1865 through about 1920 include Scotch hearth and reverberatory furnace smelting. These technologies are described below.

The roast-reduction reaction whereby lead sulfide reacts with lead oxide to produce metallic lead and sulfur dioxide gas is very important in the metallurgy of lead, making it possible to smelt lead sulfide directly to metal by controlled oxidation. Lead smelting was conducted by prehistoric man, and the phenomenon of roast-reduction made it possible to recover molten lead from its ores by a process that was not much more complex than simple melting. The principal disadvantage of the method as usually employed is that the temperature is not high enough to produce a molten slag; consequently, reduction is not complete and much of the reduced lead remains entrained in the mass of solid gangue minerals.

Smelting in the Ore Hearth. This method was used for treating coarse high-grade galena ores. Lead ore was mixed with a small amount of coke and treated in a small hearth equipped with tuyeres blowing air into the ore to oxidize the galena. Part of the sulfide would burn and the resulting lead oxide would then react with more galena (roast-reduction) to produce metallic lead. The molten lead was collected in the furnace hearth.

In the operation of the ore hearth, the charge was frequently stirred and new charge added as required. The workmen withdrew sticky portions of the charge to the "work stone" in front of the hearth, made a rough separation of slag and partly fused charge, returned the latter to the hearth, and removed the former. Lead overflowed continuously from the well through a spout. Some hearths were water cooled, others were air cooled. The slag removed from the hearth was high in lead and amounted to about 15 percent of the charge to the ore hearth. There was a high fume production. A concentrate with at least 70 percent lead was required for successful ore hearth treatment. Silica could not exceed 2 percent and iron 4 percent. Lower grade material caused excessive quantities of slag and attendant high lead loss. The concentrate should preferably be 3/16 inch or coarser so the air could penetrate, and the lead could filter through. The charge should preferably be silver-free because of the possibility of fume loss.

With the development of reverberatory and blast furnace smelting technologies about 1900, ore hearths were soon abandoned. The hearths were small and required considerable attention; they recovered only 60 to 85 percent of the metal, and the slag produced as a residue had to be resmelted somewhere if they were to operate economically. The process was not suitable for ores containing less than 70 percent lead, and it could not be used for silver-bearing ores, because a great deal of silver was lost by volatilization. Ore hearths were used, however, between about 1865 and 1920 to treat some of the high-grade silver-free ores and concentrates of St. Francois County.

Reverberatory Lead-Smelting Methods. Lead has been treated by reduction smelting in reverberatory furnaces in which the reducing agent was mixed with the solid charge on the hearth. This method is no longer used in the United States for smelting lead ores.

Various types and sizes of furnaces have been used, and the operations differ somewhat in details. In most cases, however, the hearth is made to slope in such a way that metallic lead will drain to one side or out of the furnace. A typical reverberatory furnace lead smelting operating cycle would be:

1. Charge the ore and give it a partial roast to produce some lead oxide but leave also some sulfide. Mix thoroughly in the furnace.

2. Close the furnace and raise the heat to promote the following reactions:

   $PbS + 2PbO = 3Pb + SO_2$
   $PbS + PbSO_4 = 2Pb + 2SO_2$
   $PbS + 2PbSO_4 = Pb + 2PbO + 3SO_2$
   $PbS + 3PbSO_4 = 4PbO + 4SO_2$

   The lead which is formed trickles to a lead sump.

3. Repeat above steps if necessary, until practically all of the sulfide is decomposed.

4. Mix some coal with the charge and raise the heat. The coal reduces remaining lead oxide. Lime may be mixed with the charge to assist in freeing lead from sulfur and to make the charge less sticky.

5. Rake out the residue and put a new charge in the furnace.

Reverberatory furnace lead smelting residues are usually high in lead. Additionally, there are high labor costs, high fume losses, and low tonnage throughput in treating lead ores in a reverberatory furnace, and unless the slags are reworked, lead loss is excessive. Reverberatory furnaces were used, however, between about 1865 and 1920 to treat some of the high-grade, silver-free ores and concentrates of St. Francois County.

2.5 Geologic History

2.5.1 Overview

The southeast Missouri lead district, located about 70 miles south of St. Louis, embraces four important sub-districts and several minor ones. The important sub-districts, in order of discovery, are Mine La Motte, the Old Lead Belt, Indian Creek, and the Viburnum, or New, Lead Belt. Descriptions that follow are of the geology and ore deposits of the Old Lead Belt.

The ore deposits are stratiform in character and are localized in a narrow carbonate bar and algal reef environment on the flanks of exposed Precambrian rocks of the St. Francois Mountains. Ore structures include a variety of primary depositional features such as pinch-out zones, disconformities, ridge structures, reefs, and submarine gravity slides. Faulting, prior to and during ore deposition, "prepared" the host rock, and strongly fractured areas are mineralized much more intensively and extensively than unfractured parts of the same sedimentary structures. The deposits are epigenetic in character.

Mineralization is believed to have occurred at the time that post-Lower Ordovician faulting took place. The mineralizing solutions are believed to be concentrated brines from adjacent basins that moved out of the basins during faulting, uplift, and erosion of the St. Francois positive area.

The southeast Missouri Lead Belt is one of the world's largest lead mining districts, having produced the equivalent of more than 9,000,000 tons of pig lead. At least 90 percent of this production has been from the area which is generally referred to as the Old Lead Belt. The area is located about 70 miles south of St. Louis in St. Francois County, centering on the town of Flat River. The southeast Missouri ore deposits are stratiform in the Upper Cambrian Bonne Terre dolomite and represent a classic example of the Mississippi Valley type.

The Lead Belt is located on the northeastern edge of the Precambrian igneous core of the St. Francois Mountains. Topography is somewhat dependent on the rock formations at the surface in any given area, but in general, it is classed as mature. The igneous rocks were eroded into mature topography of considerable relief prior to deposition of the Upper Cambrian sediments. Later erosion stripped the sedimentary cover from many of the higher knobs and modified their surface expression. They appear as large, rounded, sugarloaf hills and represent the highest elevations in the area.

The non-cherty Bonne Terre, Davis, and Derby-Doe Run formations erode more easily than the younger cherty formations and have the gently rolling appearance of late maturity. The cherty formations develop a thick residuum on narrow, sharp ridges with underdeveloped flood plains along streams.

The Big River and its tributaries drain most of the district except for the extreme southwestern part, which is drained by the St. Francois River system. Both streams flow in an entrenched meander system indicating uplift and rejuvenation.

As used here, "Bonne Terre" and "Lamotte" refer to the Upper Cambrian rock formations, while "Bonne Terre" and "La Motte" refer to geographical locations, principally towns, communities, or mine units.

2.5.2 Geologic History and Stratigraphy

The lead producing area of Missouri is located on the flank of a somewhat circular-shaped positive structure known as the St. Francois Mountains, the northeastern part of the Ozark dome. The core of this structure is formed by Precambrian igneous rocks, mainly rhyolitic porphyries intruded by granite and diabase rock. Many of the erosion-formed igneous knobs are exposed at the surface, and others remain buried by Cambrian and Ordovician sedimentary formations.

The sedimentary formations in order of deposition are: Lamotte sandstone, Bonne Terre formation, Davis shale, Derby-Doe Run dolomite, Potosi dolomite, Eminence dolomite, Gasconade dolomite, Roubidoux formation, and Jefferson City dolomite. The Cambrian-Ordovician division is considered to be at the top of the Eminence dolomite.

The Lamotte sandstone is mainly a pure orthoquartzite with occasional siltstone sections or dolomitic beds in the upper part. It is generally fine grained, friable, cross-bedded, and often porous and permeable. Near the base or on the flanks of igneous knobs it may be conglomerate or arkosic. The maximum thickness is about 450 feet.

The Bonne Terre formation is composed almost entirely of dolomite in the mining region although it is predominantly limestone beyond it. Dolomite, thought to be of digenetic origin forms a halo of uneven size and shape around Precambrian igneous knobs that are high enough to extend into or through the Bonne Terre. The paleotopographic highs also affected sedimentation, giving rise to a different Bonne Terre facies on or near the structure as compared with that farther into the basin. Sea currents, influenced by the larger igneous masses, built ridges or spits of elastic carbonate material.

During an early period of geologic study, Jewell and Wagner subdivided the Bonne Terre formation into zones numbered from 1 through 19, from the top down. The major units are shown in Figure 1. Detailed descriptions of the units are given by Ohle and Brown and by Snyder and Odell who describe the zones as follows:

"All zones ore generalized lithologic type. The zones are predominantly tan crystalline calcarenite - alternating with gray or brown shaly carbonate of varied texture. The lower units, 10 through 19, differ considerably in thickness or may be absent. Where a unit thins, the adjacent one thickens, so that the overall thickness of the formation is about the same throughout the central productive area.

"The 19 bed is a sandy dolomite regarded as the transitional phase between the Lamotte quartz sand and the Bonne Terre carbonates. The transitional unit is a member of the Bonne Terre formation and, in many areas, is separated by a sharp hiatus from the underlying sandstone. Quartz sand of the transition unit represents reworked Lamotte. Quartz-bearing beds of the 19 unit intertongue with quartz free Bonne Terre units on the flanks of depositional ridges. The 15, 10, and 5 units are composed predominantly of tan, crystalline calcarenite; in many places the 10 and 5 are oolitic. "The 15 and 10 units are markedly lenticular, strongly cross-bedded and variable in thickness. The 12 and 7 beds, are gray to brown shaley dolomite of varied lithologies. The 7 bed represents the main period of algal reef formation. Where algal formation is restricted or lacking, the unit is composed of grey shaley dolomite like the 12 unit.

"Calcite limestone, designated as the 11 bed rarely is cut by mine workings. Away from mine workings and off the ore-bearing structure it is penetrated by many drill holes, most commonly within the upper part of the 12 and the lower part of the 7, although in places the entire section from the top of the 19 to the bottom of the 5 is limestone. Lithologic character of the limestone has had little detailed study but most of the textural variations occurring in dolomite also are found in limestones.

"One unusual rock type, classed as the 9 unit, is a sedimentary breccia of limited areal and stratigraphic extent. It represents a primary product of slump in shaly 12 or 7 beds. It is common in the 12 but may occur at any position in the lower 200 feet of the formation, except in the tan crystalline units."

In the description above and in what follows, it is important to note that all of the Bonne Terre dolomite was deposited as limestone. The terms calcarenite for lime sand and calcilutite for lime mud are used here to indicate character at deposition although these rocks are all now dolomite.

The lithologies of the Bonne Terre dolomite have been described in terms or four end member components. These are algal material, sand size gains (carbonate, fossil fragments, quartz), calcareous mud, and argillaceous mud. A given bed may be composed of any one of the components or any combination, depending upon the environment of deposition. In addition, finely divided digenetic iron sulfide is a common constituent of the fine-grained carbonates and argillaceous sediments. It imparts a gay color to the carbonates and a black color to the shales as contrasted with the tan and brown colors due to iron oxide in the coarse-grained carbonates.

The Davis shale conformably overlies the Bonne Terre formation. It is composed or interbedded shales, carbonates, fine-grained glauconite sandstones and glauconitic siltstones. Flat pebble and edgewise conglomerates are characteristic of the Davis. The formation averages 170 feet in thickness.

The Derby-Doe Run dolomite consists of two major units. The lower is composed of thin-bedded argillaceous dolomite, the upper of massive oolitic dolomite or algal reef dolomite. This formation is transitional into the Potosi formation above. The Potosi is a brown, massively bedded, siliceous dolomite consisting to a large degree of algal reef and recrystallized oolitic dolomite. The silica is present in the form of handed calcedonic and quartz druses. The Eminence and Gasconade formations contain clean, light gray, medium to coarsely crystalline, cherty dolomites. Widespread masses of silicified cryptozoon beds are present. The Roubidoux consists of sandstone, dolomitic sandstone, and cherty dolomite. The Jefferson City formation is composed principally of tan and gray, medium to finely crystal, line, cherty and argillaceous dolomite. A pronounced erosional unconformity is present at the top of the Jefferson City group.

The forms of ore bodies basically, are the form of sedimentary depositional structures in the Bonne Terre host. Almost every conceivable primary structural feature that could be developed during shallow water carbonate deposition is represented. In places in the district, postlithification faulting has disrupted primary structures; mineralization on opposite sides of the fault may not he uniformly related to sedimentary features. In places faulting has resulted in mineralization of beds not normally mineralized. In places, also, solution and oxidation of carbonate host, some of it possibly pre-ore, disturbs the intimate relationship of ore and primary structures. However, recognition of the Bonne Terre facies pattern is essential to understanding lateral and vertical variations in form, characteristics, and stratigraphic position of ore bodies.

The Old Lead Belt is contained in a barrier reef and related carbonate facies developed along the north edge of the St, Francois Mountains that formed an island complex in late Cambrian time. The Precambrian surface of the Missouri platform was one of low relief with scattered areas that stood several hundred to over a thousand feet above the general erosional level. Over this irregular surface, the Lamotte sandstone was deposited. Irregularities on the Precambrian are reflected by subdued but definite irregularities on the top of the Lamotte.

The Bonne Terre formation in the Old Lead Belt consists of: 1) dolomite back reef facies several miles in width, composed almost entirely of medium- to coarse-grained calcarenite and oolite, 2) dolomite reef facies 3 to 4 miles in width in which the lower 100 feet of the Bonne Terre shows extensive lateral facies changes from calcarenite bars to local basin sediments, with the bar facies overlain by the 100 foot thick algal reef zone, and 3) narrow dolomite fore-reef zone that interfingers into limestone.

The back-reef area is unmineralized, except along its northeastern fringe where depositional structures have a northwest-trend parallel to the old shoreline. Mineralization in this northwest-trending belt is at the zone 7/10 contact and locally extends up to 50 feet into the zone 7 reef.

The lower 100 feet of Bonne Terre in the reef facies zone contains a wide variety of depositional structures; disconformities, over-lap features, and pinch-out zones; and great lateral variations in lithology. A series of northeast-trending calcarenite bars was developed, over which the algal reefs grew, so the lower 200 feet represents a complex of stratigraphic and reef structures. The bar-reef complexes, sometimes called structural centers, were major sites for ore deposition.

Outward from the bar-reef complex, the dolomite passes into limestone, in part oolitic but dominantly shaly and fine-grained. There is no mineralization in the limestone, although some limestone "islands" are present in the district and are cut by haulage drifts.

At the close of the deposition of the lower 200 feet of Bonne Terre the control exerted by the irregular basement surface had been largely eliminated. The upper Bonne Terre over many hundred square miles is largely tan oolitic dolomite with only minor variations in lithology and some narrow, irregularly-trending bars.

2.5.3 Origin of Old Lead Belt Ore Deposits

Available evidence indicates the metals were brought into the Bonne Terre formation not earlier than post-Potosi time and, probably not earlier than post-Jefferson City time. Mineralization appears to have been a long slow process, but time of termination of the sulfide-deposition stage is indeterminable.

The solutions were simple in character, carrying only lead, zinc, copper, nickel, cobalt, cadmium, silver, and iron to form metallic sulfides. In addition, they may have carried magnesium, potassium, calcium, and sodium. The sulfur appears to be of biogenic origin and probably was derived from the host.

The preponderance of evidence indicates that the solutions originated in deep, adjacent sedimentary basins, possibly from both the Forest City and Illinois basins. The abundance of cobalt and nickel in Mine La Motte and eastern Lead Belt ores and their scarcity in western Lead Belt and Viburnum ores suggest an initial difference in ore-bearing fluids. There is no basis for relating the metals to the brief volcanic episodes in southeastern Missouri, and the distribution of ore relative to volcanic centers argues against a genetic connection.

The metals carried by the solutions are thought to have been deposited with the basin sediments that contain abundant shales. In addition to the well-known granites and rhyolites of the mid-continent basement, mafic intrusives, including norite, are known in the sub-surface rocks and could have been the source providence for the nickel.

It is unlikely that water of compaction was the ore fluid. Water ejected during compaction would have antedated the time of ore deposition as dated by faulting. In addition, the brines occurring in sulfides in other mid-continent ore deposits are too concentrated to fit a water of compaction hypothesis. This greater concentration of dissolved substances may have been acquired during the time the connate water remained in the basin before migration.

The brines, believed to have carried the metals, were driven out of the basins after compaction of the basin sediments. Brine movement was probably initiated by uplift and erosion of the Ozark dome, accompanying circumference faulting that upset hydrodynamic stability. Much of the brine movement was along the sediment-basement interface with only limited migration through sedimentary aquifers. Guided by basement topography, the metal-bearing brine entered the Bonne Terre formation where the Lamotte sand feathered out and Bonne Terre rested directly on the Precambrian rocks. There is no basis for postulating either juvenile or groundwater mixing with the basin brines, either as additional sources of metals or factors in transportation or deposition of metals. Likewise, there is no evidence to indicate that juvenile waters may not have contributed to the ore fluid.

The metals were precipitated as sulfides when they encountered iron-sulfide and probably hydrogen sulfide rich zones in the Bonne Terre formation, in any type of trap available.

Springs are abundant throughout the area. There are two important horizons at which springs occur most abundantly: between the Davis shale and the Derby limestone, and between the Doe Run and the Potosi formations. The Davis and Doe Run formations are each relatively impervious while above them occur more or less previous dolomites, which carry water, chiefly along bedding and jointing planes.

Some of the smaller streams in the area are fed by perennial springs. Murrill Spring, for example, supplies a small tributary of the Big River, near Bonne Terre, while Shaw spring, near

Flat River, supplies water constantly to Davis Creek, a tributary of Flat River. The number of springs varies with the rainfall and consequently with the seasons. Many springs which discharge copious amounts of clear water in the spring become either dry or stagnant pools during the summer.

3.0 SITE DATA

Previous reports and investigations were reviewed to determine the extent of data available for use in this initial RI. Table 3-1 summaries the data for each of the Big River Mine Tailings Sites (BRMTS). Upon review of the information, it was determined that sufficient data exists in a number of areas. In some instances the data was taken at one site but can be justified as being applicable to the other sites in the area because of similarities in the region, the mining operations, and the surrounding environment. For example, sampling data taken at the various sites confirm the tailings piles are similar in composition.

Information and data were compiled from 42 relevant studies and reports generated on the Old Lead Belt. Compiled from these reports, Table 3-2 identifies the number of samples taken. This sample data, along with additional sampling required to fill data needs, will form the basis of the BRMTS RI/FS.

The following sections discuss the data available and pertinent to completing an RI/FS. The first section provides a brief description of the sites as they exist today. Subsequent sections cover topography, climate, air quality, wastes, geology, soils, sediments, surface water, groundwater, land use demography, public health, and ecology. Appendix A contains sampling data extracted from the referenced reports.

3.1 Site Descriptions

The Old Lead Belt

The Old Lead Belt encompasses 110 square miles (USGS, 1988) and is bordered by latitudes $38^0 00'$ and $37^0 49'5''$ and by longitudes $90^0 37'30''$ and $90^0 28'45''$. This report evaluates eight former mining sites within the old lead belt, and sediments of the Big River:

- Desloge
- National
- Leadwood
- Elvins/Rivermines
- Bonne Terre
- Federal
- Doe Run
- Hayden Creek
- Big River Sediments

TABLE 3-1
SUMMARY OF AVAILABLE SITE INFORMATION/DATA SETS FOR EACH SITE

	Site									
	Desloge									
Site Information/ Data Set	Chat Pile	Landfill	National	Leadwood	Elvins/ Rivermines	Bonne Terre	Federal	Doe Run	Hayden Creek	Big River Sediments
Site History	X	X	X	X	X	X	X	NA	X	X
Site Plot Plan	X	X	X	X	X	X	X	NA	X	
Topographic Map**	X	X	X	X	X	X	X	X	X	X
Tailings Data	X	X	X	X	X	X	X*	NA	NA	NA
Ecological Receptors	*	*	NA	NA	NA	NA	NA	NA	NA	X
Human Receptors	X	X	*	*	*	*	*	*	*	*
Soil[a]	X	X	NA	X	NA	NA	NA	NA	NA	NA
Sediment	*	*	X*	X*	X*	X*	X*	NA	NA	*
Groundwater	X	X	NA	X	X	NA	NA	NA	NA	NA
Surface Water (Wetlands)	X	X	X*	X*	X	NA	NA	NA	NA	*
Air Quality[a]	X*	X*	NA	NA	NA	NA	X*	NA	NA	NA

Key: X = Adequate information available
NA = Not available at this date
* = Some data is available
** = USGS
[a] Data is available for soil, air quality, tailings and ecology. Specific data gaps will be addressed by proposed sampling (Refer to Section 5.0)

Source: Fluor Daniel, 1995

TABLE 3-2
VALIDATED SAMPLE QUANTITIES

Sample Type	No. of Samples
Tailings/Chat	648*
Soil	246*
Sediment	52
Groundwater	107
Surface Water	37
Biota	242
Air	49

Note:
* Validated samples meet EPA Data Quality Objectives Level III and IV.
Source: Fluor Daniel, 1995

Figure 3-1 shows the location of the eight sites included in this report.

Desloge Site

The 540-acre Desloge site boarders the city of Desloge in St Francois County and is located within a meandering four-mile loop of the Big River. The property contains a 95-acre chat pile, *4 acres of development and shaft rock, and a 40-acre landfill. The St Francois County Environmental Authority owns the property to the east and south of the site. The site is bounded on the east by the city of Desloge, on the south by a semi-rural area containing several private homes, and on the southwest by a river access area owned by the Missouri Department of Conservation (MDC). The Big River forms the property line for some four miles on the west and north sides of the property. The property can be located on the Bonne Terre and Flat River 7 1/2 minute, USGS quadrangle maps in Sections 25, 26, 35, and 36, Township 37 North, Range 4 East. The existing Desloge site is shown in Figure 3-2.

National Site

The National site consists of 175 acres within the city of Flat River. Properties north and east of the site are owned by the Flat River Chamber of Commerce. The site contains a 44-acre chat pile and a flat tailings area directly to the east. The entire site is essentially barren. The property is bounded on the south by the city of Elvins and on the north by the cities of Desloge and Park Hills. It can be located on the Flat River 7 1/2 minute, USGS quadrangle map in Section 12, Township 36 North, Range 4 East and Section 7, Township 36 North, Range 5 East (Figure 3-3).

Leadwood Site

The Leadwood site consists of 528 acres of flat, inactive tailings ponds (most of which support a good stand of vegetation) and a 35-acre chat pile. The site is bounded on the east by the city of Leadwood and on the south by the community of Wortham. It is shown on the Flat River 7 1/2 minute, USGS quadrangle map in Sections 4, 5, 8, 9, and 16, Township 36 North, Range 4 East. Figure 3-4 shows the Leadwood site.

The Leadwood site has two tailings retaining structures that have been classified as dams. The Leadwood structure, with a height of 60 feet, captures a drainage area of just over 3 square miles, while the Eaton Structure with a height of 38 feet captures drainage from part of the same area.

Elvins/Rivermines Site

Elvins is a 149-acre site within the city of Rivermines. A chat pile covers 72 acres of the site, a tailings pond, the remainder. The property is bounded on the south by the city of Elvins and on the north by the cities of Flat River and Rivermines. The property, as shown in Figure 3-5, can be located on the Flat River 7 1/2 minute, USGS quadrangle map in Section 12, Township 36 North, Range 4 East and Section 7, Township 36 North, Range 5 East.

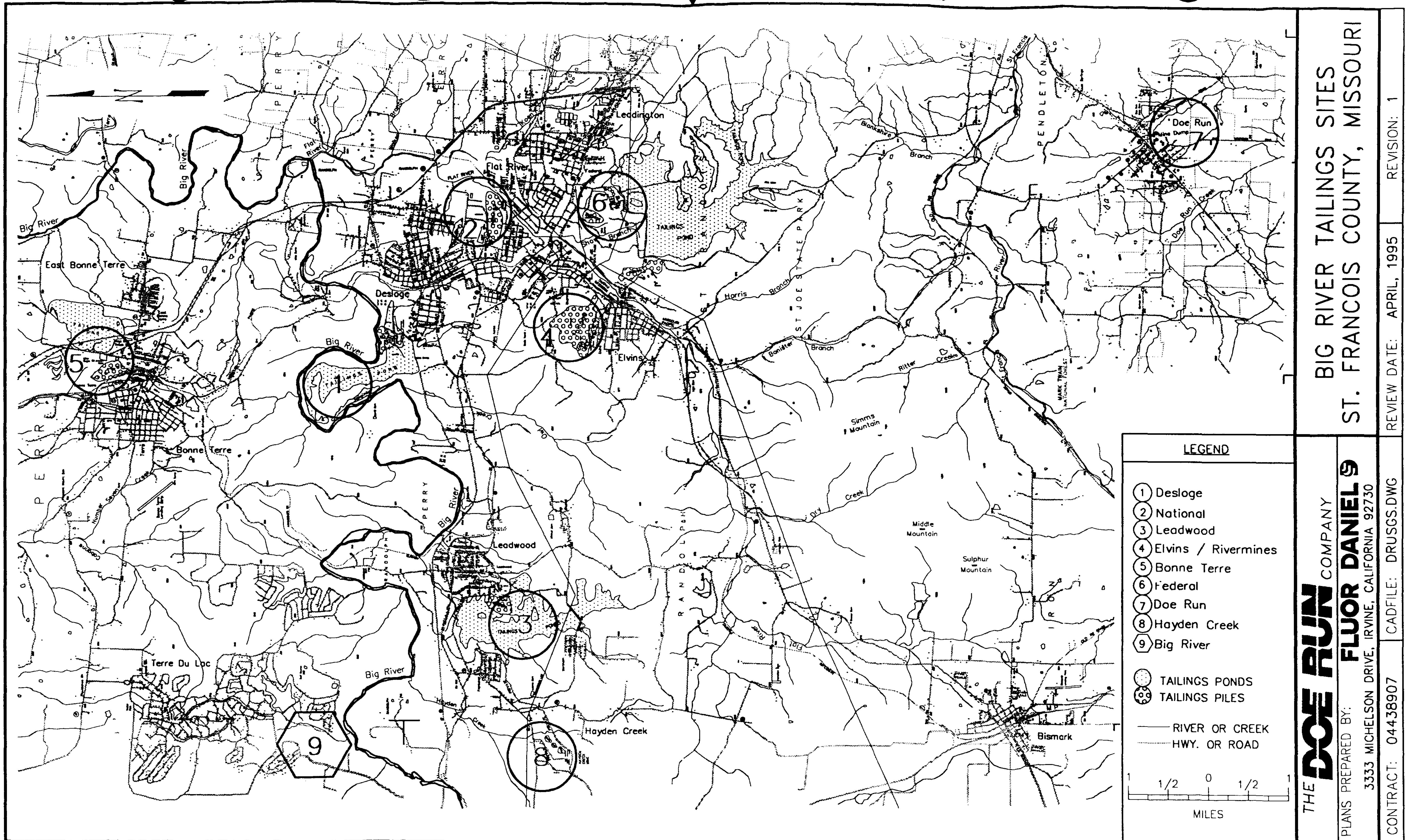
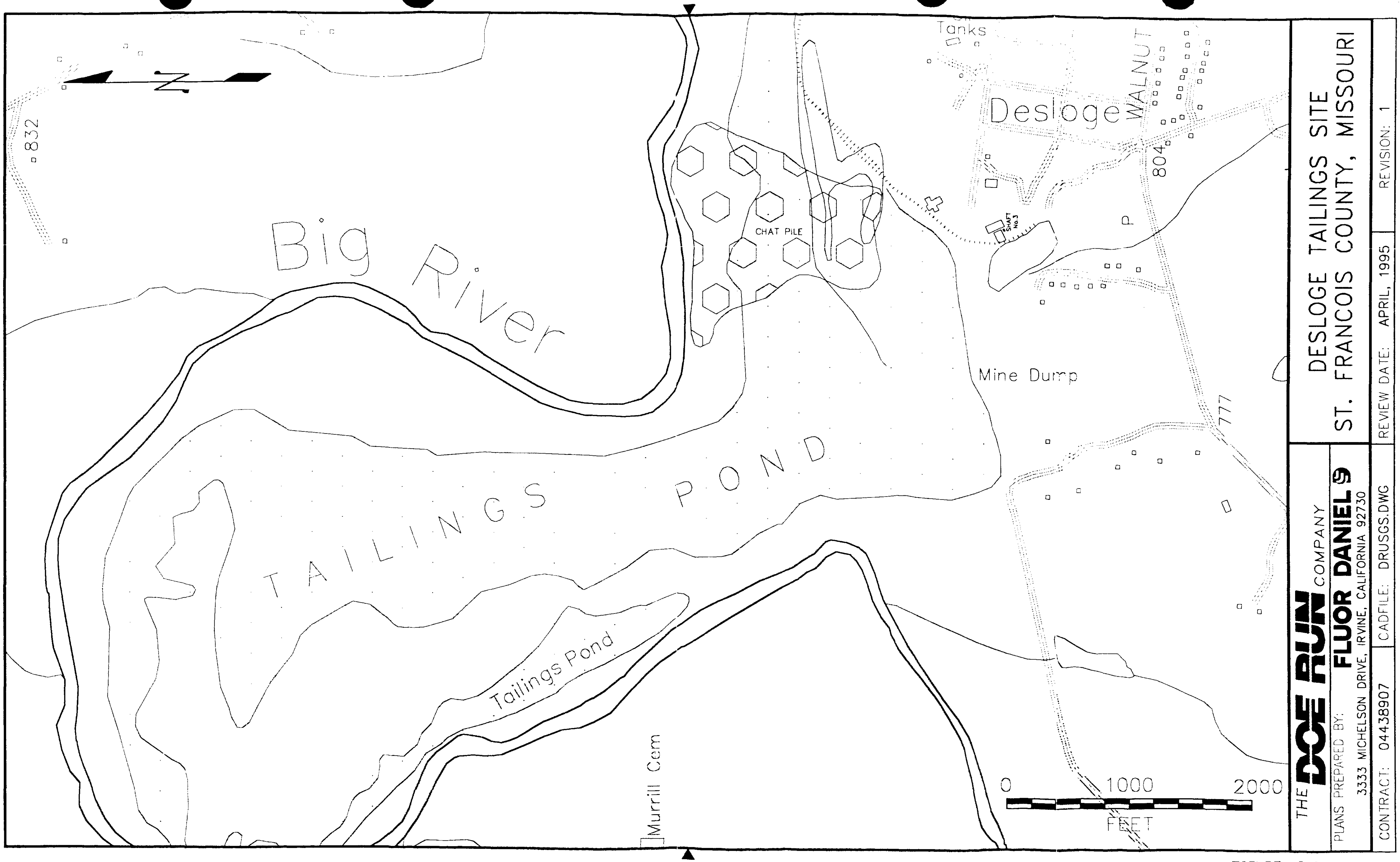

BIG RIVER TAILINGS SITES
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CONTRACT: 04438907
CADFILE: DRUSGS.DWG
LEGEND
1 Desloge
2 National
3 Leadwood
4 Elvins / Rivermines
5 Bonne Terre
6 Federal
7 Doe Run
8 Hayden Creek
9 Big River
TAILINGS PONDS
TAILINGS PILES
RIVER OR CREEK
HWY. OR ROAD
1 1/2 0 1/2 1
MILES
N
Leadington
Flat River
Desloge
East Bonne Terre
Bonne Terre
Big River
Elvins
Leadwood
Terre Du Lac
Hayden Creek
Bismark
Doe Run
Simms Mountain
Middle Mountain
Sulphur Mountain
Harris Branch
Ritter Creek
Dry Creek
Blankshire Branch
Doe Run Creek
ST JOE STATE PARK
PERRY
RANDOLPH
PENDLETON
ST FRANCOIS

FIGURE 3-1



N
832
Big River
Tanks
Desloge
WALNUT
804
SHAFT No.3
P
CHAT PILE
Mine Dump
777
TAILINGS POND
Tailings Pond
Murrill Cem
0
1000
2000
FEET
DESLOGE TAILINGS SITE
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CONTRACT: 04438907
CADFILE: DRUSGS.DWG

FIGURE 3-2

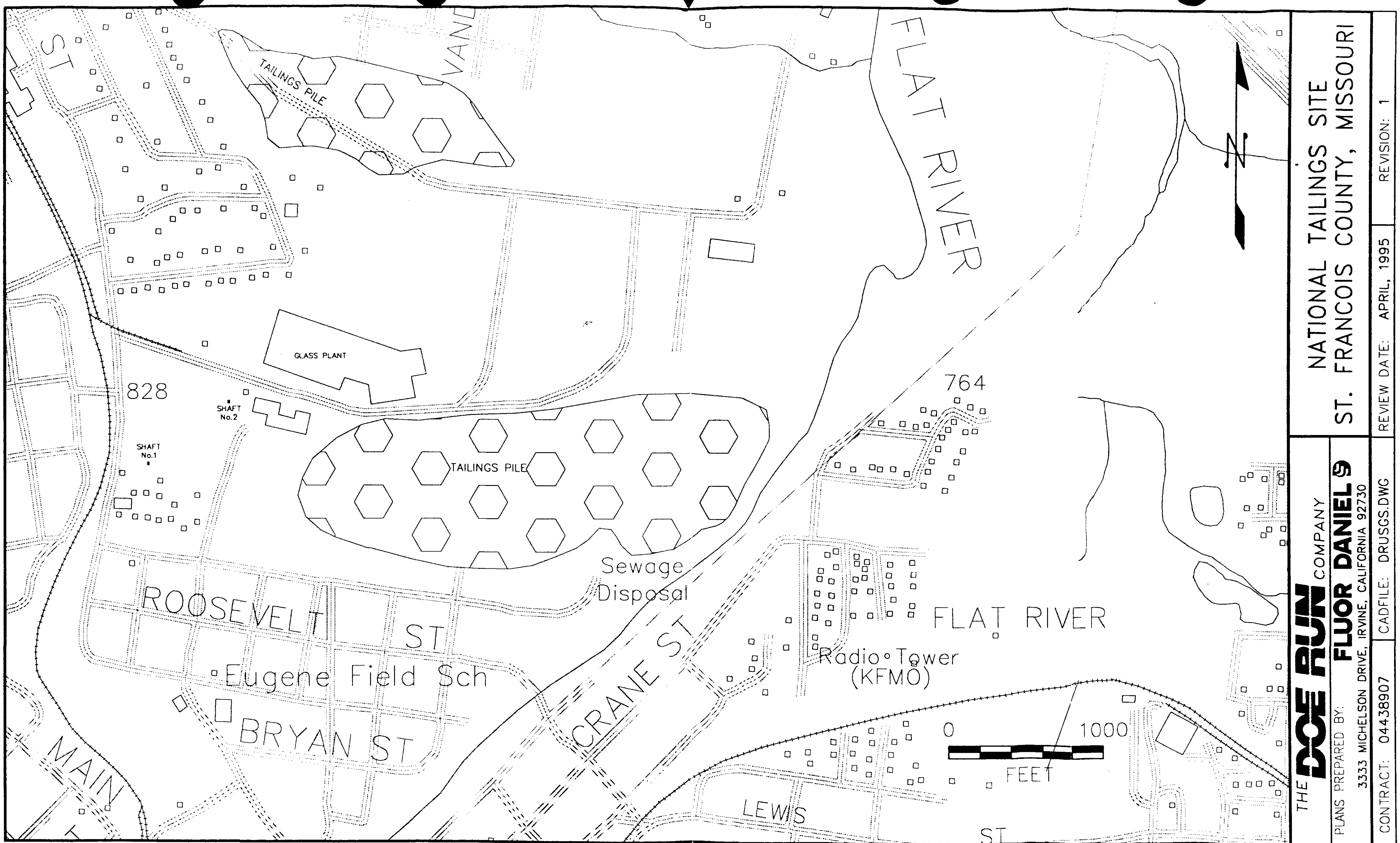
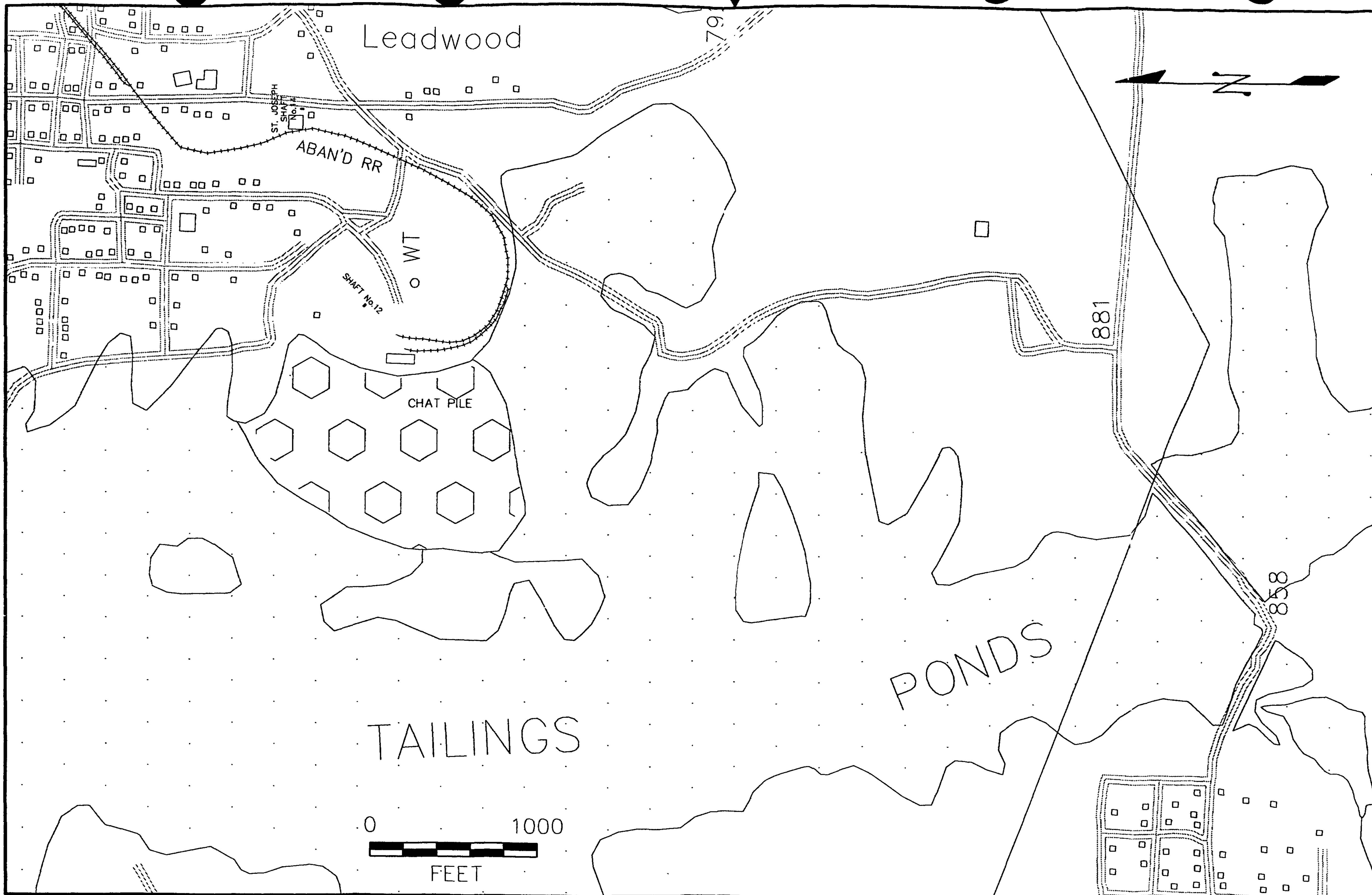

TAILINGS PILE
VAND
FLAT RIVER
GLASS PLANT
828
SHAFT No.2
SHAFT No.1
TAILINGS PILE
764
Sewage Disposal
ROOSEVELT ST
Eugene Field Sch
BRYAN ST
MAIN
CRANE ST
Radio Tower (KFMO)
FLAT RIVER
0
1000
FEET
LEWIS
ST
NATIONAL TAILINGS SITE
ST. FRANCOIS COUNTY, MISSOURI
REVISION: 1
REVIEW DATE: APRIL, 1995
THE DOE RUN COMPANY
FLUOR DANIEL
PLANS PREPARED BY:
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CADFILE: DRUSGS.DWG
CONTRACT: 04438907

FIGURE 3-3



LEADWOOD TAILINGS SITE
ST. FRANCOIS COUNTY, MISSOURI

REVIEW DATE: APRIL, 1995

REVISION: 1

THE DOE RUN COMPANY

PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730

CONTRACT: 04438907

CADFILE: DRUSGS.DWG

FIGURE 3-4

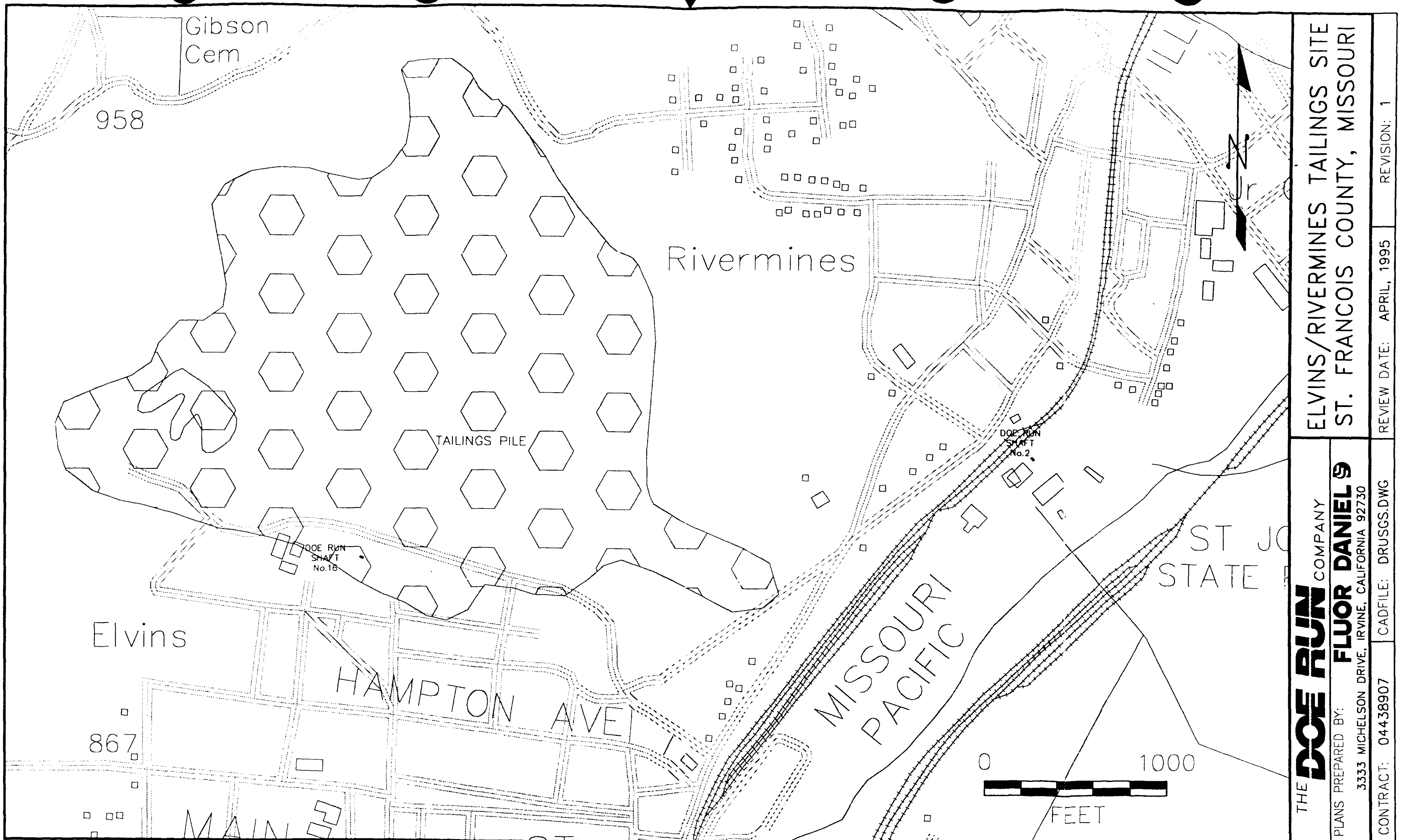

Gibson
Cem
958
Rivermines
TAILINGS PILE
DOE RUN
SHAFT
No.2
DOE RUN
SHAFT
No.16
Elvins
HAMPTON AVE
867
MAIN
MISSOURI
PACIFIC
ST JO
STATE
0
1000
FEET
N
ELVINS/RIVERMINES TAILINGS SITE
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CONTRACT: 04438907
CADFILE: DRUSGS.DWG

FIGURE 3-5

Bonne Terre

The Bonne Terre consists of two tracts separated by a small portion of the outskirts of the city of Bonne Terre and by U.S. Highway 67. The portion of the property lying east of Highway 67 consists of approximately 300 acres, of which approximately 295 are dry tailings with very little vegetation and less than 5 are tailings covered by water. Highway 67 forms the western boundary of this property for its entire length. West of Highway 67 the property of 50 acres, of which 39 are covered by a chat pile and 11 by tailings and/or chat. This latter area is bounded on the west and south by the city of Bonne Terre, on the east by a light industrial area and a cemetery, and on the north by a golf course. The property can be located on the Bonne Terre 7 1/2 minute USGS quadrangle map, in Sections 11 and 12, Township 37 North, Range 4 East.

The portion east of Highway 67 was sold to a private owner about 1965. The portion west of Highway 67 (the chat pile and associated tailings/chat disposal area) are believed to be still owned by St. Joe. A golf course lies on the northwest side of the site and a cemetery on the west side of the site. A residential area and school are located to the southwest of the site. Refer to Figure 3-6 for details of the Bonne Terre.

Federal Site

Federal (St. Joe Park) encompasses 1135 acres, including a 1005-acre tailings pond, 50 acres of buildings, 43 acres of development rock (poor rock), and 37 acres of revegetated disturbed area (Sears, 1985). The area is located south of the cities of Flat River and Leadington and east of the cities of Rivermines and Elvins. It is shown on the Flat River and Farmington 7 1/2 minute, USGS quadrangle maps in Sections 9, 10, 11, 16, 17, 18, 19, 20 and 21, Township 36 North, Range 5 East. In 1976, St. Joe deeded the entire area to the MDNR Division of Parks and Historical Preservation for use as a state park. The state then built a campground, several restrooms, a picnic area, a paved 11-mile bicycle trail, and an equestrian trail, and began turning the milling area into a museum. It designated the entire flat tailings area for off-road recreational vehicle activity. Figure 3-7 shows the Federal site.

Doe Run Site

The Doe Run Mine operation was located on 30 acres. This site included a 9-acre chat pile and a processing area (Sears, 1985). The property lies just south of the community of Doe Run in a rural area. It can be located on the Wichita Mountain 7 1/2 minute USGS quadrangle map in Section 16, Township 35 North, Range 5 East. St. Joe sold the property to a private individual in 1977. Figure 3-8 shows the Doe Run site.

Hayden Creek Site

Hayden Creek Mine consisted of eight acres with buildings and a processing area. Ore from this mine was transferred to Leadwood for processing (Sears, 1985).

The Hayden Creek mine was located in the West 1/2 Section 7, Township 36 North, Range 4 East, St. Francois County, as shown in Figure 3-9. The mine was on the west edge of the Old Lead Belt. Neither the ore body nor the underground workings were connected with those of any other mine in the district.

3.2 Topography

There are three very well marked divides in the Old Land Belt area. The longest divide extends in a general westerly direction from a point about a half-mile south of Bonne Terre. This divide separates the northward and southward flowing tributaries of the Big River. It is thought that the somewhat flat tops of the ridges and hills marking this divide indicate one or more stages of base leveling and that the gentle slope to the east is simply a result of differential erosion.

The second divide commences at the junction of the Big and Flat rivers and separates the Big River from the Flat River and its chief tributary in this area. This divide has a general southwesterly course and then a southerly course terminating just south of Bismark, where it unites with the divide separating the St. Francois River from the Big River and its tributaries.

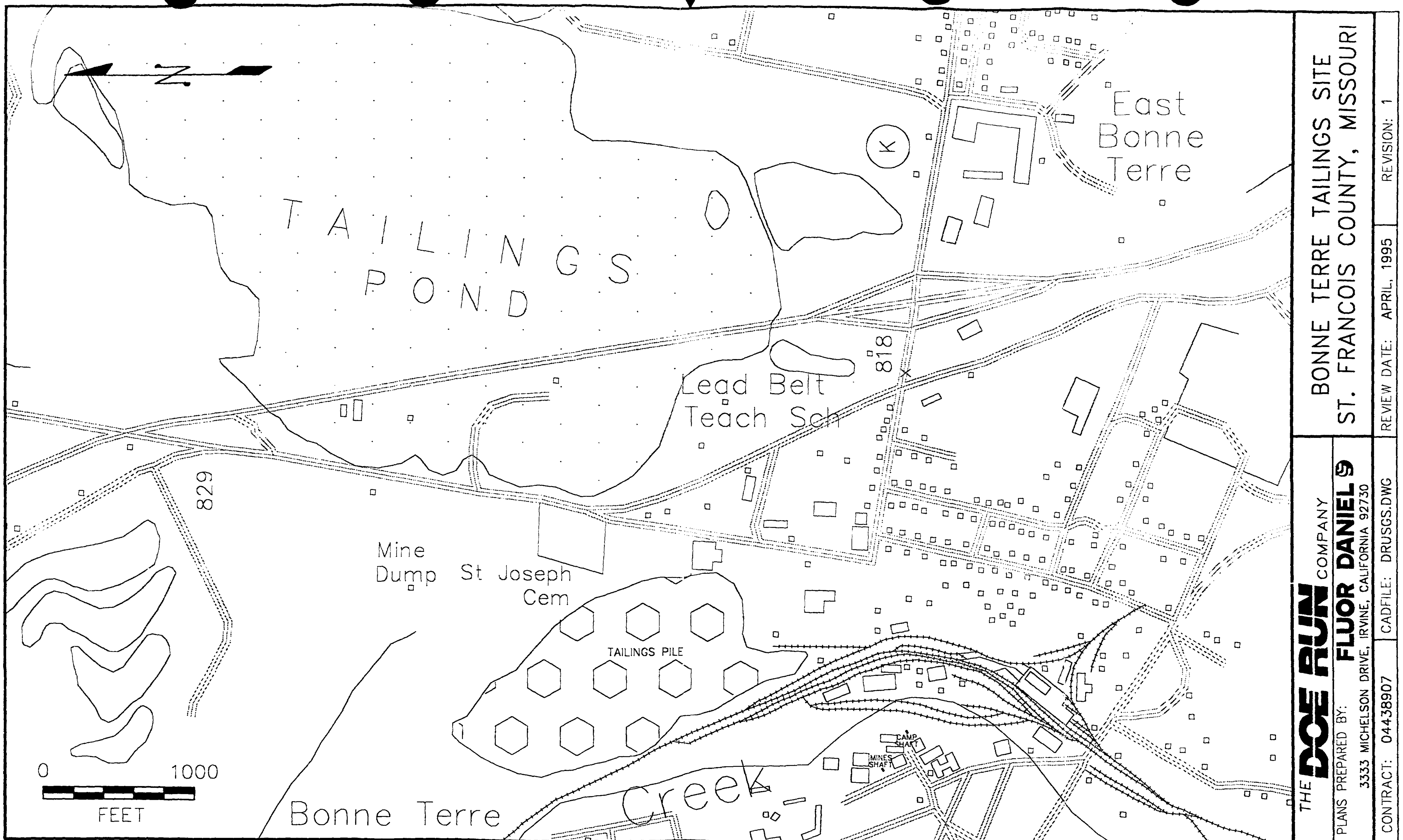

TAILINGS POND
East Bonne Terre
K
818
829
Lead Belt Teach Sch
Mine Dump
St Joseph Cem
TAILINGS PILE
CAMP SHAFT
MINES SHAFT
Bonne Terre
Creek
0
1000
FEET
BONNE TERRE TAILINGS SITE
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CONTRACT: 04438907
CADFILE: DRUSGS.DWG

FIGURE 3-6

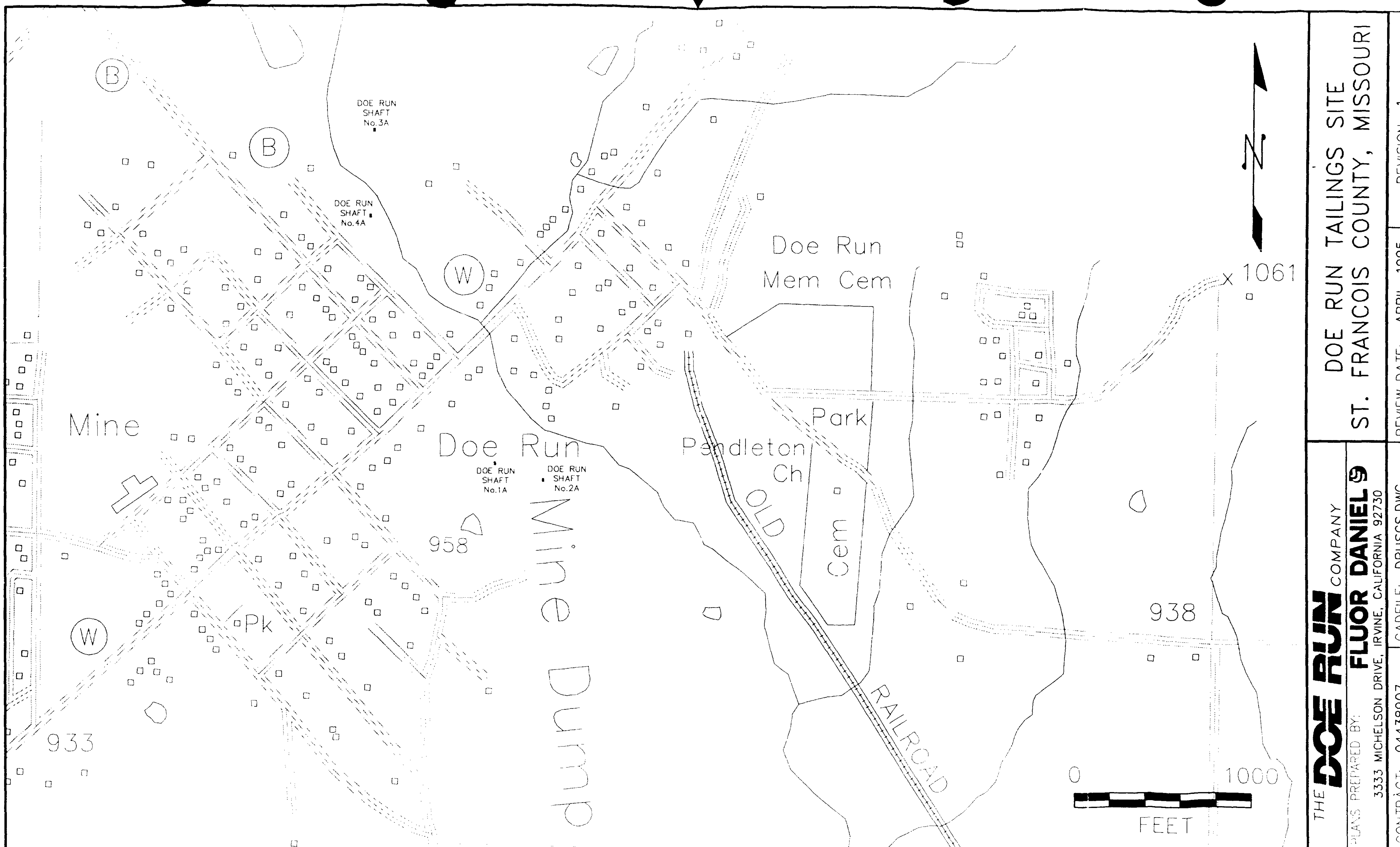

DOE RUN SHAFT No.3A
DOE RUN SHAFT No.4A
DOE RUN SHAFT No.1A
DOE RUN SHAFT No.2A
Doe Run
Mine
Mine Dump
Doe Run Mem Cem
Park
Pendleton Ch
Cem
Pk
OLD RAILROAD
958
933
938
x 1061
0
1000
FEET
DOE RUN TAILINGS SITE
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY:
FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CONTRACT: 04438907
CADFILE: DRUSGS.DWG

FIGURE 3-8

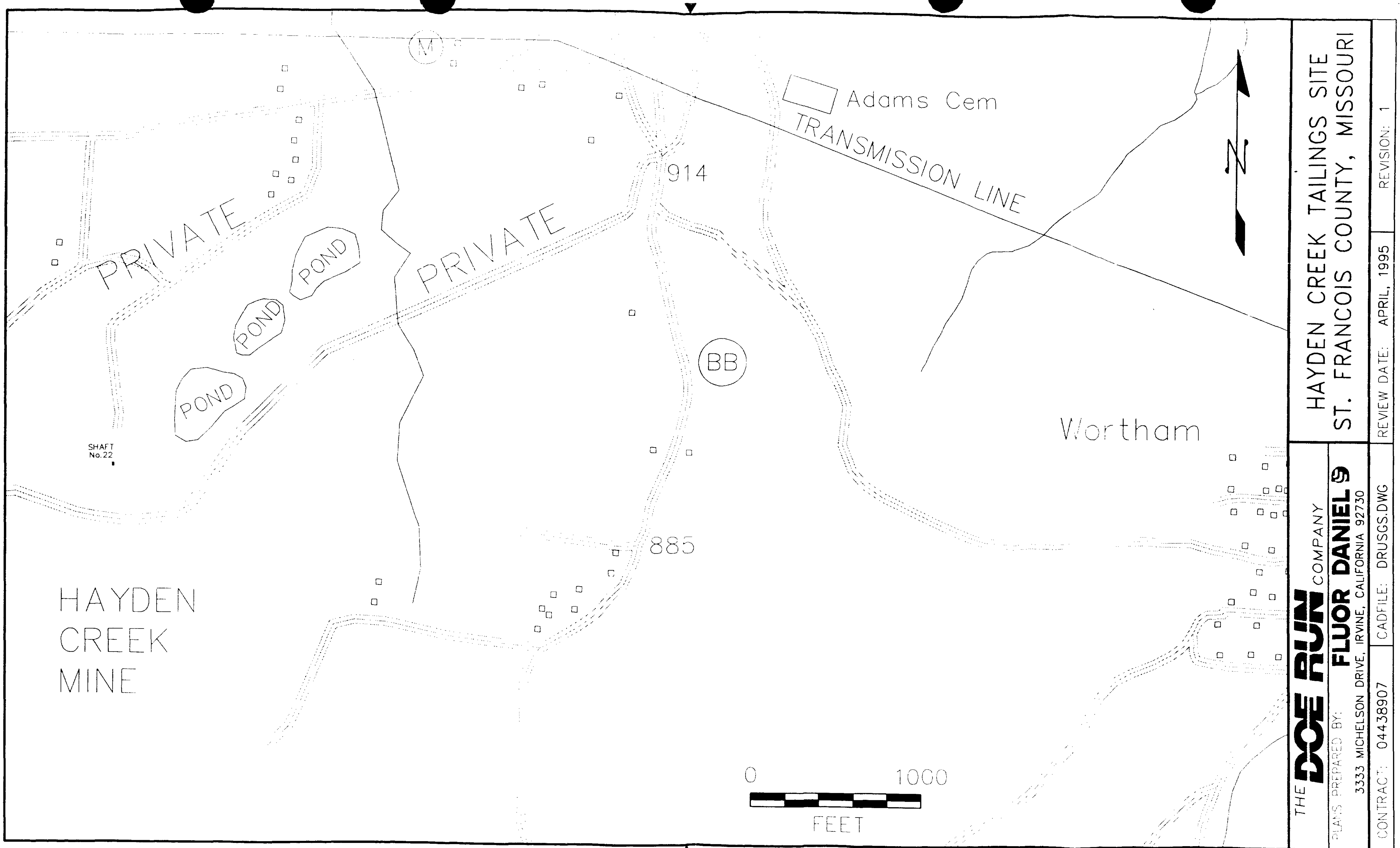

Adams Cem
TRANSMISSION LINE
914
PRIVATE
PRIVATE
POND
POND
POND
SHAFT No.22
BB
M
Wortham
885
HAYDEN CREEK MINE
0 1000
FEET
N
HAYDEN CREEK TAILINGS SITE
ST. FRANCOIS COUNTY, MISSOURI
REVIEW DATE: APRIL, 1995
REVISION: 1
THE DOE RUN COMPANY
PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730
CONTRACT: 04438907
CADFILE: DRUSGS.DWG

FIGURE 3-9

The third divide separates St. Francois River and its tributaries from the Big River and its tributaries. This divide has a general northeast-southwest course and is very irregular. This divide shows a much more irregular profile than the two preceding, because it passes over several peaks of igneous rock. As a rule, the divides are narrow. The flattest and broadest is that portion separating Flat and Big rivers. This divide has an elevation of about 1000 feet, and the slopes on either side are gentle.

The ridges and hills that mark the divides between the rivers and their tributary streams are usually flattopped and terminate at an elevation of from 960 to 1040 feet. The chief level is 1000 feet, above which rise mounds and hills of sedimentary rock from 20 to 200 feet high (Welch, 1995).

As previously noted, the topography for the Old Lead Belt consists of gently rolling hills with narrow table plain areas containing creek and river depressions. The southwestern portion of the county is mountainous. The lowest point in the study area is 680 feet, along the Big River where it exits St. Francois County. The highest point is the summit of Meade Mountain, 1530 feet above sea level. Between the lowest and highest points of the sites there is a difference in elevation of 320 feet.

As a whole, the district is rough and hilly. The areas that might be called mountainous are in the southeastern and southwestern parts of the county in which occur the northern spurs of the granite and rhyolite hills of the St. Francois Mountains. These ridges, spurs, and peaks of igneous rock are the remnants of a lofty range of mountains that occupied this section of the state in pre-Cambrian times. These peaks and ridges are known locally by various names, such as Simms, Meade, Sulphur, Hughes, and Round mountain. They are especially conspicuous features of the landscape, rising from 300 to 500 feet above the level of the surrounding country. They are interesting as an instance in which the oldest rocks of an area occupy the highest elevations.

The granite and rhyolite hills and ridges are steep sided, and near their bases occur talus slopes concealing underlying formations. The hills and ridges usually have flat tops which are covered with a thin mantle of soil. Around the margins of these flat tops, igneous rocks outcrop at intervals, exposing smooth surfaces, some of which exhibit a remarkably small amount of decomposition.

For the most part, the sites are located in the table-land areas. These appear to indicate an early period of base-leveling (Buckley, 1908). The following table provides elevations for the study sites and approximate elevations of tailings at each site.

TABLE 3-3
ESTIMATED TAILINGS ELEVATIONS

Site	Grade Elevation at Base of Pile	Pile Elevation
Desloge	800 - 840	908
National	740 - 800	994
Leadwood	830	1020
Elvins/Rivermines	800	NA
Bonne Terre	900	966
Federal	900	NA
Doe Run	1000	Removed
Hayden Creek	800	NA

Note:
NA = Not Available
Source: Fluor Daniel, 1995

3.3 Climate

St. Francois County's climate is essentially continental with frequent changes in the weather both from day to day and season to season. Winters are cold and summers hot. Temperatures over 100°F are rare. In the summer, temperatures rise to 90°F or higher an average of 40 to 50 days. Temperatures below 0°F are infrequent but have occurred in the county. In the winter, temperatures at 32°F and below occur on an average of 120 days.

In the winter, the average temperature is 35°F and the daily minimum temperature is 24°F. In the summer, the daily average maximum is 88°F with an average temperature of 75°F.

Annual precipitation in this area averages approximately 40 inches. The greatest 24-hour rainfall was 4.95 inches at Farmington, 5 miles southeast of Desloge. Average annual snowfall is 13.7 inches.

Generally the prevailing winds in the area are from the south. From an air monitoring station located at Desloge the wind speed ranged from 4 to 8 miles per hour from the south and southeast.

3.4 Air Quality

Air quality data has been collected by Missouri Department of Natural Resources (MDNR) at St Joe Park. MDNR used Hi-vol samplers at nine locations, beginning in 1981 and continuing to the present day. The samples were analyzed for total suspended particulate (TSP) only. Tables 3-4 and 3-5 provide results from this sampling.

TABLE 3-4
AIR SAMPLING DATA FOR TSP

YEAR	SAMPLED TSP* ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
1981	56.00	75.00
1982	65.00	75.00

*Arithmetic mean
Source: MDNR, 1995
NAAQS = National Ambient Air Quality Standard

TABLE 3-5
AIR SAMPLING FOR LEAD

Year	St. Joe Park Location	Lead TSP ($\mu g/m^3$)[a]	NAAQS for Lead ($\mu g/m^3$)[b]
1993	Missouri Mines	0.06	1.5
	Park Garage	0.06	1.5
	South Side	0.05	1.5
1994	Missouri Mines	0.07	1.5
	Park Garage	0.07	1.5
	South Side	0.06	1.5

[a]Arithmetic mean
[b]8-hour average
NAAQS = National Ambient Air Quality Standard
Source: MDNR, 1995

The results from these tests were within the standards for air quality for this area.

All of the sites with tailings have similarities to the Federal site in tailings composition, approximate elevation, lack of vegetative growth,and wind characteristics. Generally, as noted in Section 3.3, the winds are from the south. The intensity of the winds vary from season to season and month to month. As shown in Section 3.5, the tailings have similar concentrations of metals. Elevations of the piles vary but are approximately 160 feet above grade in most cases, as shown in Table 3-3. Even though the air data was for a specific site (Federal), similar results would be expected at other tailings sites.

3.5 Wastes

Wastes generated in the lead mining and milling operations include tailings, chat, and poor (development) rock. Approximately 250 million tons of tailings and chat were produced in the Old Lead Belt until the last mine closed in 1972. The majority of the tailings and chat were deposited at six major tailings piles: National, Federal, Desloge, Elvins, Leadwood, and Bonne Terre. Doe Run has a smaller tailings deposits and Hayden Creek does not have tailings. The Doe Run tailings have essentially been removed.

The tailings at Leadwood, Desloge, National, Elvins, and Bonne Terre have been extensively characterized for metals concentration including lead, cadmium, and zinc (Wixson, 1983). Table 3-6 presents the results of this sampling analysis showing ranges of metal concentrations.

TABLE 3-6
SITE METAL CONCENTRATIONS

Site	Source	No. of Samples	Pb (μg/g)	Cd (μg/g)	Zn (μg/g)
Desloge	1	NA	1776.3	14.76	697.9
	2	24	1200-3400	15-87	900-4100
	3	4	1300-2500	NA	NA
	4	74	826-6200	6.8-78.6	233-3990
National	1	NA	3420	13	NA
	2	112	950-17000	0.3-94	31-4200
	4	93	1640-9283	3-87	87-5055
Leadwood	4	108	589-17000	9.3-1870	633-25000
	2	24	440-6300	42-200	2000-11000
Elvins/Rivermines	4	91	851-11600	19.8-202	108-900
	2	30	1500-1600	14-20	1800-63000
Bonne Terre	4	35	1300-7010	3-29.5	51.3-967
Federal	5	NA	580-2830	NA	NA
Doe Run	NA	NA	NA	NA	NA
Hayden Creek	NA	NA	NA	NA	NA

Sources:
1. Schmitt and Singer, 1982
2. Wixson
3. EPA, 1991c
4. Wixson, 1983
5. ATSDR 1994

NA = Not Available

3.6 Geology

3.6.1 Overview

The Old Lead Belt of southeastern Missouri consists of Cambrian formations resting on an eroded sequence of Precambrian formations (Harris, 1991).

The Lamotte formation lies directly above the Precambrian formations. This sandstone varies between 0 and 100 feet in thickness. There is a conglomerate at the base of the sandstone. Above the conglomerate is a medium grained sandstone which is interbedded with shale in some lower portions. Some of the unweathered portions of the formation consist of a nearly white, clean quartz.

The Bonne Terre formation overlies the Lamotte sandstone. This formation varies between 350 to 400 feet in thickness. The Bonne Terre is the major ore bearing formation in the Old Lead Belt region of southeast Missouri. The most important mining zones in the formation are:

- Dense grey dolomite
- Bluish grey and white dolomite
- Thick-bedded tan, often oolitic dolomite
- Reef zone
- Coarsely crystalline, tan,or light dolomite
- Thin-bedded, fine grained dolomite
- Coarsely crystalline, light grey dolomite, often glauconitic
- Sandy dolomite

A stratigraphic column, Figure 3-10 illustrates the local geology.

The forms of ore bodies basically are the form of sedimentary depositional structures in the Bonne Terre host. The primary structural features that can be developed during shallow water carbonate deposition are represented. In some places in the district, postlithification faulting has disrupted primary structures; mineralization on opposite sides of the fault may not be uniformly related to sedimentary features.

3.6.2 Mineralogy of the Deposits

The primary sulfide minerals include galena, sphalerite, chalcopyrite, siegenite, bravoite, marcasite, and possibly bornite and millerite.

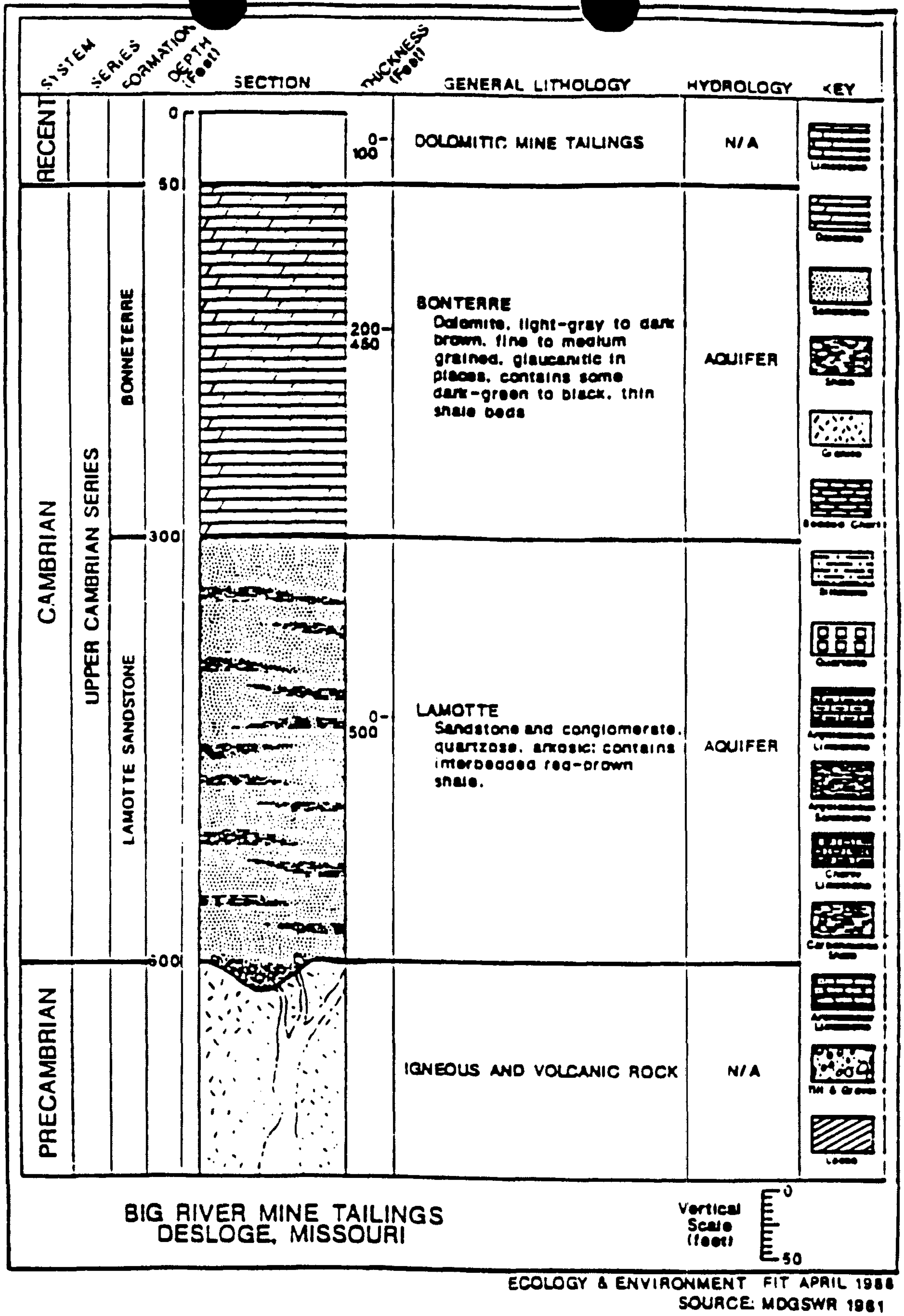


FIGURE 3-10 GENERALIZED STRATIGRAPHIC COLUMN

Galena occurs as bedded or sheet deposits along disconformities and bedding planes, in part as replacements but locally as open space fillings; also as disseminated crystals and crystalline aggregates in several types of dolomite and black shales and as fracture fillings. Massive bedding seams of solid galena up to 18 inches thick, are a mosaic of very fine to coarse-grained crystals, frequently with a layered appearance due to alternately fine and coarse sulfides. Curved cleavage planes are common. In a few areas, galena along bedding planes is thoroughly crushed and smeared. However, uncrushed and undeformed galena also is abundant.

Sphalerite, although a minor constituent for the district as a whole, may be abundant locally. It is usually dark in color, fine-grained and occurs as disseminations in the dolomite host. Many sphalerite crystals have alternating wedges that appear yellow and purple in transmitted light, presumably a twinning effect. Euhedral crystals are rare and, when found coating fractures, are seldom more than 1/8 inch in diameter.

The sphalerite is restricted to certain parts of the district and in these areas commonly is associated with gray shaly dolomite and black shale. In this respect, it appears to be much more closely tied to a particular host rock facies than is galena. The sphalerite usually occurs with galena but invariably is with or above the stratigraphically highest galena mineralization.

Chalcopyrite is abundant in the eastern part of the district and is rare in the western part. The copper mineral occurs as disseminations in nearly all Bonne Terre lithologies and as thin seams along bedding planes. Where it occurs chalcopyrite usually is with or below the stratigraphically lowest galena, its most common occurrence is in lower Bonne Terre.

Siegenite, a cobalt-nickel sulfide, is present in minor amounts, usually in small disseminated crystals. In a few areas in the eastern and southern part of the district it occurs as seams up to 3 inches thick along bedding planes. The siegenite is present in many copper-bearing specimens and its district occurrence is closely related to that of copper. In some instances, siegenite is associated with pyrite rather than chalcopyrite but its occurrence is restricted to the copper-bearing area.

Bravoite is present in very small amounts. Bravoite was discovered in Missouri ore by Rasor who stated that this was the first reported occurrence of this mineral in North America. The mineral occurs as minute crystals in, and thin coatings on, pyrite and also replaces siegenite.

Marcasite is abundant. It occurs intimately mixed with all ore minerals and also as massive aggregates without associated ore minerals.

3.7 Soils

The soils, with the exception of the alluvial tracts along the rivers, are mainly residual. Much of the area underlain with the Potosi formation has a heavy, clayey soil, while the surface is often strewn with fragments of chert or flint. In places, the flint fragments are so abundant as to render the land almost useless for agriculture. Where the land is underlain with rock belonging to the upper part of the Potosi, it is frequently sandy from the decomposition of sandstone which occurs in the upper part of this formation or above it.

The country underlain with the Derby, Doe Run, and Bonne Terre formations usually has a red, clayey surface soil, although there are frequently areas from which the residual material from the Potosi has not yet been removed. The usual soil resulting from the decomposition of the Bonneterre formation is more fertile than that derived from the Potosi. However, it is usually thin and ledges of dolomite frequently outcrop at the surface, even where the ground is comparatively level.

The Davis shale produces a clayey soil often somewhat sandy. The soil resulting from the decomposition of this formation is usually better than that of any of the other formations. Disintegration is more regular and proceeds faster. The residual material is thicker, since less of the formation is removed in solution by the underground waters.

The Lamotte sandstone results in a sandy soil, having very little virtue for agriculture. However, it is often mixed with the residual clay from the higher formations, by which it is tempered to a degree which makes it very excellent.

The igneous areas are chiefly found in the shape of steep sided hills and ridges where there is little chance for soils to accumulate. The soils, wherever they occur, however, are generally productive. The tops of the granite and rhyolite ridges are narrow and the hillsides are covered with talus.

In Sections 8, 9, 16, 17, 20, 21 and 22, T. 36 N., R. 5 E., in the southeastern part of the Flat River-Leadwood areas, the residual deposits are, in places, unusually thick. Drill holes in this area have passed through over 180 feet of residual clay, some of which contained large and small boulders of flint.

Through the movement of the chat and tailings material as a result of wind and erosion from surface runoff and the past use by area residents as backfill, agricultural lime, engineering fill for highways, and other highway applications the material has co-mingled with virgin soils in the area.

Soil samples have been collected in a number of areas surrounding the sites. At Desloge 30 samples were collected in 1990 (EPA, 1991c). The report indicates that several these samples are not valid because QA/QC procedures were not followed. Table 3-7 shows the results of this sampling effort.

TABLE 3-7
METAL CONCENTRATION IN SOILS

Site	No. of Samples	Pb (mg/kg)	Cd (mg/kg)	Zn (mg/kg)
Desloge	6*	99-2200	<1.2-270	42-490

Note:
* Valid samples
Source: EPA, 1991c

3.8 Sediments

Sediment samples were collected from the Big River in 1983 (EPA, 1991c) and July 1990 (Desloge EECA). In the 1984 study, the highest concentrations were found in the Big River near Eaton Creek at Leadwood. Samples taken at this location have previously indicated high levels of lead at this confluence: 173000 and 49000 μg/g. Samples taken at other locations of the Big

River range from 14 to 12000 μg/g. Table 3-8 summarizes the sediment sampling data available for use in the RI.

TABLE 3-8
METAL CONCENTRATIONS IN SEDIMENTS

Site	Source	No. of Samples	Pb (μg/g)	Cd (μg/g)	Zn (μg/g)
Big River at Desloge	2	NA	2215	39.96	1658.4
	5	NA	350-10000	6.1-130	290-6700
	6	24	1200-3400	15-87	900-4100
	4	17	1000-3000	NA	NA
National Influent Sediment	4		3420	13	NA
Big River at Leadwood	1	6	3900-173000	210-770	39000-84000
	4	11	14-49000	NA	NA
Elvins/Rivermines	1	Composite Average	3900	35	36200
Bonne Terre	3	NA	107	5730	NA
Federal (Influent Sediment)	1	Average	3.36 mg/l	10 mg/l	441 mg/l
Doe Run	DG	DG	DG	DG	DG
Hayden Creek	DG	DG	DG	DG	DG

Sources:
1. Summary of damage cases from the Disposal of Mining Wastes
2. Schmitt
3. Gale, 1986
4. Wixson, 1983
5. EPA, 1991c
6. Hemphill

DG Data Gap
NA Not Available

3.9 Surface Water

The study area is drained by the Big and St. Francois rivers and their tributaries. The former is by far the most important, draining approximately 210 of the 230 square miles of territory inside the study area. The Big River rises in the northern part of Iron County, flows northeast through the southeastern part of Washington County, then east with many meanders to the center of St. Francois County. It then flows north and northwest into Jefferson County and from there in a general northerly direction, emptying into the Meramec River at the northern boundary of Jefferson County.

Although the meandering course of Big River gives it the appearance of a stream that has reached maturity, it flows in a channel bounded by a very narrow flood plain, hemmed in on either side by bluffs from which steep cliffs often come down to the waters edge. The meandering character of this river is characteristic of most streams in the Ozark region, including the Osage, Meramec and Gasconade rivers.

The principal streams and tributaries to the Big River within the study area include Flat River, Eaton Creek, Hayden Creek, Owl Creek, Dry Creek, Wallen Creek, Cedar Creek, Terre Bleu Creek, Coonville Creek, Bee branch and Peters Creek entering from the east and south; and Cadet Creek, Mill Creek, Three Hill Creek, Bear Creek and Hopewell Creek entering from the west and north. Figure 3-11 highlights the water bodies in the portion of St. Francois County being studied.

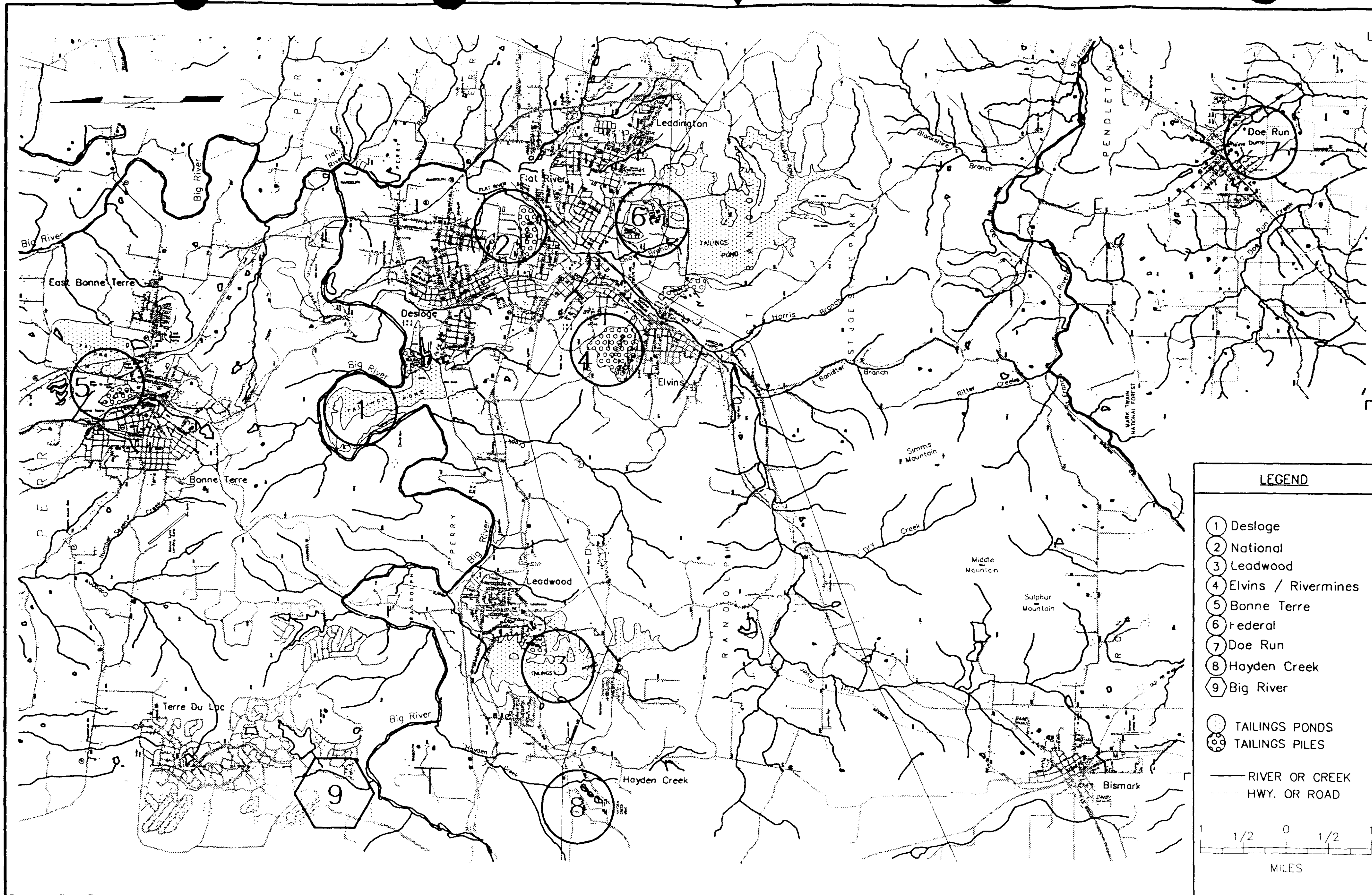
The Flat River, the most important tributary, rises in the hills directly west of Bismark, flows north skirting the crystalline area, and then northeast, emptying into the Big River just outside of the area included in this report.

Dry Creek rises in the hills of crystalline rocks just west of Bismark, flows in a northerly and then northwesterly direction through the town of Irondale, emptying into the Big River about three-quarters of a mile north of that town.

Wallen Creek rises in the hills about three miles south of west of Bismark, and flows north and then northwest joining the Big River about three and a quarter miles southwest of Irondale.

Cedar Creek rises in the southwest, flows nearly due north and joins the Big River about three and a half miles from its source.

Eaton Creek rises in the hills about four miles west of Elvins, flows a little east of north and joins Big River about two and a half miles from its source.



SURFACE WATER
ST. FRANCOIS COUNTY, MISSOURI

REVIEW DATE: APRIL, 1995

REVISION: 1

THE DOE RUN COMPANY

PLANS PREPARED BY: FLUOR DANIEL
3333 MICHELSON DRIVE, IRVINE, CALIFORNIA 92730

CADFILE: DRUSGS.DWG

CONTRACT: 04438907

FIGURE 3-11

Hayden Creek has its source in the hills about one and a half miles west of the source of Eaton Creek, flows in a general northerly direction and empties into the Big River about three miles from its source.

Owl Creek rises in the hills in Sections 10, 11, 14 and 15, T. 36N., R.4E, flows a little east of north, emptying into the Big River northeast of Desloge.

Terre Bleu Creek rises in the northeastern part of the area, flows generally south emptying into the Big River about two miles northeast of the city of Bonne Terre.

Coonville Creek also rises in the northeastern part of the area, flows southwest emptying into the Big River about three miles a little east of north of the city of Bonne Terre.

Bee branch rises near the northern boundary of this area, about one and a quarter miles from the northeast corner, flows southwest, emptying into the Big River about three miles from its source.

Peter's Creek rises in the hills near the northern boundary of this area and flows southwest, emptying into the Big River about two miles from its source.

Mill Creek has its source in the hills south and southwest of Mineral Point. It flows generally northeast for about five miles where it receives a tributary, from the west, known as Keyes branch. It then flows east for a mile and a half, making a wide bend to the north about five miles south of where it joins the Big River.

Three Hill Creek rises in the hills about four and a half miles southwest of Mineral Point and flows a little west of north for about five and a half miles, where it empties into the Big River.

Bear Creek rises in the hills about a mile and a half northeast of the source of Three Hill Creek, flows about four miles almost due north and empties into the Big River about a half a mile from the mouth of Three Hill Creek.

Hopewell Creek rises about a mile south of Summit flows about three and a half miles southeast, where it empties into Big River.

In addition to above named bodies, there are numerous short and unnamed branches, most of which are southward flowing tributaries of the Big River.

For six miles, the St. Francois River flows in a southwesterly direction across the southeastern corner of this area. Part of its course is between steep bluffs, the remainder through a narrow flood plain. It receives several small tributaries, the principal being the Doe Run branch. This stream rises in the hills about three miles south of Elvins and flows south for a mile and a quarter, emptying into the St. Francois River about a mile and a half west of Loughboro. The St. Francois River empties into the Mississippi River about fifty miles south of Memphis, Tennessee.

Some of the local streams, like Davis Creek, lose their water thorough crevices that carry it underground. Other streams are fed by springs which render them perennial. However, many of the smaller tributaries are maintained entirely by surface drainage and are, as a result, intermittent. Likewise, many of the local springs are intermittent which means, in turn, that the volume of water carried by the perennial streams fluctuates very greatly from one season to another. Again, some of the streams are perennial through portions of their course and intermittent through the remaining distance. Davis Creek, a tributary of Flat River, for example, is fed by springs but during dry spells the water all disappears in a zone of faulting which crosses the channel about a mile from its mouth. Another perennial spring contributes a supply of water to the creek about a half a mile from its mouth, so that both the upper and lower reaches of the stream are perennial while a stretch of about a half a mile near the middle of the course is intermittent.

All of the streams rise very quickly after heavy storms. This condition results in the streams periodically scouring their beds down to underlying rock.

Surface water samples have been taken at Desloge, National, Leadwood, and Elvins (Table 3-9).

TABLE 3-9
METAL CONCENTRATIONS IN SURFACE WATER

Site	Source	No. of Samples	Pb	Cd	Zn
Big River at Desloge	2	TMC	0.041-0.110 (mg/l)	0.001-0.004 (mg/l)	0.11-0.36 (mg/l)
	5	NA	0.020 (mg/l)	0.002 (mg/l)	0.31 (mg/l)
	4	NA	6-61 μg/l	NA	42-1300 μg/l
	3	19	5.9-59 ppb	NA	NA
National	1	NA	NA	NA	0.9-4.82 (mg/l)
Leadwood	3	3	5-8 ppb	NA	NA
Elvins/Rivermines	1	Maximum	0.15	0.04	0.05-5.2

Sources:
1. Summary of Damage Cases From the Disposal of Mining Wastes
2. Schmitt and Singer, 1982
3. Wixson, 1983
4 EPA, 1991c
5. EAE, 1988

NA Not available
TMC Total Metal Concentration

3.10 Groundwater

Groundwater from the mines or wells alongside of the mines have been used as sources of potable water for 70 years while the mines operated. Active mining operations ceased in the Old Lead Belt when the Federal mine closed in 1972. The interconnected mine caverns underlying communities in the Old Lead Belt have since filled with water.

The Lead Belt Water Company incorporated as a public utility in 1935, and subsequently the Flat River Water District supplies the communities of Park Hills (formerly Flat River, Elvins, Ester, and Rivermines) Desloge, and Leadington. The portion of the flooded mine at Rivermines and a well near Desloge supply a population of approximately 12,100. The Leadwood Water Company supplies the city of Leadwood, and the city of Bonne Terre is supplied by the Flat River Water District but from a well in the area.

Beginning in 1965, analyses were made to detect the presence of heavy metals in the water. Table 3-10 shows a representative results of these analysis for the years 1965, 1982, and 1984.

TABLE 3-10
METAL CONCENTRATIONS (ppm) IN GROUNDWATER,
THREE YEARS

Metal	1965	1982	1984
Arsenic	0	<0.005	<0.005
Selenium	0	<0.0025	<0.005
Lead	0.007	<0.01	0.015
Cadmium	0	<0.005	<0.005
Barium	NA	<0.2	<0.2
Chromium	0	<0.025	<0.025
Silver	NA	<0.01	<0.01
Iron	NA	1.27	1.91
Manganese	NA	0.17	0.24
Zinc	<0.6	0.32	0.28
Copper	0	0.08	0.01
Sodium	NA	11.1	10.9
Potassium	NA	2.4	3.9
Mercury	NA	<0.0005	<0.0005
Floride	NA	0.12	0.18
Nitrate-N	NA	<0.05	<0.05

Note:
* < = Indicates chemical concentration was either zero or less than the detection limit.
Sources: Sears, 1985
NA Not Available

The pH of local groundwater is normally slightly alkaline because the water comes in contact with carbonate rock and dolomite. An alkaline pH will restrict the mobility of metals and minimize the impact of the natural occurring metals.

Springs are abundant throughout the area. There are two important horizons at which springs occur most abundantly: between the Davis shale and Derby limestone, and between the Doe

Run and Potosi formations. The Davis and Doe Run formations are each relatively impervious while above them occur more or less porous dolomites, which carry water, chiefly along bedding and jointing planes.

Some of the smaller streams in the area are fed by perennial springs. Murrill Spring, for example, supplies a small tributary of the Big River near Bonne Terre, while Shaw spring, near the Flat River, supplies water constantly to Davis Creek, a tributary of the Flat River. The number of springs varies with the rainfall and consequently with the seasons. Many springs which discharge copious amounts of clear water in the spring become either dry or stagnant pools during the summer.

Four spring samples were collected and analyzed at Desloge along the Big River (EPA,1992). These springs drain directly into the river. Subsequently, the results from these samples were determined to be invalid by approved QA procedures.

A review of the past reports has not identified the number of private wells that exist in the Old Lead Belt. Private well sampling has been performed as part of the sampling performed in 1990 and 1991 by the ESE FIT. Table 3-11 provides results from this sampling effort.

TABLE 3-11
METAL CONCENTRATIONS IN PRIVATE WELLS

Site	No. of Samples	Pb (ppb)	Cd (ppb)	Zn (ppb)
Desloge	5	T 5.9-32.9	0	-
	2	D 6.6-25.6	-	-
	19	T -	-	T 20.1-457
	20	D -	-	P 20.3-463

Note:
T = Total
D = Dissolved
Source: EPA, 1991c

No other sampling of springs in the vicinity of the sites has been performed.

3.11 Land Use

The Old Lead Belt area contains some light manufacturing such as the glass plant located at the National site and the asphalt plant at Elvins. Much of the area is forested with some pastures for livestock and cropland. Residential areas lie within 200 feet of some of the sites, including National, Elvins, Desloge, Bonne Terre, and Doe Run.

The Big River is used for fishing and swimming. Heavy use of the river takes place at Washington State Park which is downstream of all of the sites.

Sites such as Federal and Leadwood are used by off-road vehicles. In the case of Leadwood this is an unauthorized use.

St Joe Park encompasses the Federal tailings ponds, chat piles, and processing facilities. The processing facilities, Mill No. 3, have been converted to a museum.

3.12 Demographics

Table 3-12 shows the populations for various cities and communities located around each site. The cities of Flat River, Rivermines, Elvins, and Esther have joined together to form the community of Park Hills. The combined population of these cities is 12,000. (ESE FIT, 1991). All of the sites have residential areas within one mile of the tailings.

Per the DOH report (ATSDR, 1994), the total population within one mile of the tailings at a site is approximately 20,000.

Homes near the sites are low to medium income level houses.

The racial make up of the area is 99.5 percent white.

The population of the mining area towns in St. Francois county totaled 5,000 in 1975 after the mines shut down.

TABLE 3-12
OLD LEAD BELT COMMUNITY POPULATIONS

City/Community	Population
Iron Mountain Lake	615
Flat River*	847
Desloge	4,227
Elvins*	1,431
Leadington	207
Esther*	1,008
Rivermines*	487
Leadwood	1,156
Gumbo	90
Bonne Terre	4,004
Farmington	12,001
Bismark	1,645
Balance of St. Francois County	18,488

*As of 1994, these communities combined to become Park Hills.
Sources: U.S. Bureau of the Census, 1990 and 1992 (est.)

Additional demographic data will be collected from the blood lead study to be performed by MDH, and will be added to the RI/FS.

3.13 Public Health

A preliminary Public Health Assessment has been prepared for Desloge by the MDH, Bureau of Environmental Epidemiology, in cooperation with the Agency for Toxic Substance and Disease Registry (ASTDR). The report indicates that the Desloge site is considered a public health hazard, although it also states that "it is not known if the long-term, low level exposure is causing any health problems." The report recommends conducting a health study to determine what health effects the long-term, low-level exposure to metal-contaminated mining waste has had on the public. Accordingly, a blood-lead study is scheduled to be performed by the MDH this summer. Results from this study will be incorporated into to the RI/FS. HARP is also undertaking an educational program to inform the public of potential risks.

A case-control study of lung cancer deaths and an associated environmental-factor study was performed in 1985-86. The study concluded, based on 1976-1984 statistical data, that there is an elevated lung cancer mortality rate among adult males and females for the Flat River area and St Francois County. (DOH, 1986 and ATSDR, 1994).

A blood-lead study was performed on 16 employees and residents in the vicinity of the Federal tailings pile. Of those tested, only two had blood-lead levels above 5 μg/dl, at 10 and 12 μg/dl. A survey of these two individuals indicated other potential sources for the elevated blood-lead levels.

A review of statistical data also indicated that fetal deaths, birth defects, and low birth weights were not significantly different from predicted state rates (ATSDR, 1994).

In the Preliminary Public Health Assessment for Desloge (ASTDR, 1994) ATSDR used the following reference levels to determine if a specific chemical needs further evaluation:

Metal	Reference Level
Lead	No value is presently available for lead, as it is undergoing further evaluation.
Cadmium	1 ppm, pica child EMEG
Zinc	600 ppm, pica child RMEG
Arsenic	0.4 ppm, CREG

Conclusions reached in the report (ATSDR, 1994) include:

- It is not known if there is an association between excessive smoking in the area, the measurable carcinogens in the ambient air at different times and the area's elevated lung cancer rate.

- Total lead has been found in residential soils at levels above what would be safe for a child's exposure.

- Elevated concentration levels for metals were found in dust samples from homes.

- Elevated metal levels in surface water are not expected to be of concern unless the water is used for drinking water.

- Elevated levels of lead, cadmium, arsenic and zinc have been found in surface water.

- Elevated lead levels in fish have been determined to be high enough to contribute to the intake of lead in persons who consume contaminated fish and, in-turn, increase their blood-lead level.

- Groundwater from a few private wells within a one-mile radius of the site has been found to contain lead contamination.

3.14 Ecology

The Missouri Conservation Department has designated 11 miles of the Big River, from Mammoth Road bridge to Brown's Ford Road bridge in Jefferson County, approximately 20 miles downstream from the Desloge site, as a Special Black Bass Stream Management Area. There are no other known sensitive environments or critical habitats within 1 mile of the site according to the MDOH and the U.S. Department of Interior.

Aquatic Life

As part of an investigation conducted in 1982 by the National Fisheries Laboratory tissue samples were collected at locations on the Big River. The highest lead concentrations (140 μg/g) in crayfish samples were found near the Desloge site. Analysis of Redhorse sucker samples also indicated elevated lead levels in fish collected near the site (90.57 μg/g) as compared to those upstream (0.02 μg/g). The dietary limit recommended by the World Health Organization (WHO) for Redhorse sucker is 0.3 μg/g. MDOH issued a press release, cautioning persons not to consume bottom-feeding fish taken from a 5-mile stretch of the Big River from the city of Leadwood (near the BRMT site) downstream to Ashington State Park (Schmitt, 1982). See Table 3-13 for details.

TABLE 3-13
METALS CONCENTRATIONS (μg/g) IN EDIBLE PORTIONS
OF FISH IN THE BIG RIVER

Location/Species	Lead	Cadmium	Zinc
Mineral Fork			
Smallmouth bass	0.19	0.01	13.97
Yellow bullhead	0.13	0.02	5.67
Redhorse sucker	0.08	0.01	13.42
Brown's Ford			
Smallmouth bass	0.21	0.01	4.50
Flathead catfish	0.29	0.02	12.24
Redhorse sucker	0.63	0.01	11.67
Washington State Park			
Smallmouth bass	0.27	0.01	9.49
Flathead catfish	12.00	0.34	23.00
Redhorse sucker	0.43	0.01	9.38
Mixed suckers	0.38	----	----
Desloge			
Smallmouth bass	0.05	0.01	11.73
Channel catfish	0.13	0.03	5.12
Redhorse sucker	0.57	0.03	16.15
Mixed sucker	0.79	----	---
Irondale			
Smallmouth base	0.01	<0.01	13.28
Flathead catfish	0.06	0.06	6.75
Redhorse sucker	0.02	0.01	9.32
Mixed sucker	0.07	----	---

Note:
*Means of two samples (individual fish) unless otherwise indicated. Reporting unit is μg/g wet weight.
Source: National Fisheries Research Laboratory Report (Schmitt, 1982).

Wetlands

The St. Joe Minerals property near Leadwood consist of one large (52-acre) palustrine emergent and shrub wetland between the Leadwood and Eaton dams. Other ecosystems on the property include wooded slopes, disturbed areas, unvegetated chat piles, and mine tailings disposal areas. The wetland area consist of about 28 acres of emergent plant species, primarily cattail, soft rush and rough horsetail, and 24 acres of willow scrub area. Uplands are dominated by eastern red cedar and oak/dogwood/hornbeam.

The function and value associated with wetlands are often an important aspect for consideration. Since the wetlands are located in tailings, a determination of function and values in relation to COPC retention is questionable. From general observations the wetlands provide sediment retention, nutrient transformation, flood water storage, and wildlife habitat (Fluor Daniel, 1991).

Available lead content in vegetables in the Old Lead Belt and New Lead Belt samples are summarized in Tables 3-14 and 3-15.

TABLE 3-14
LEAD CONCENTRATIONS OF VEGETABLE CROPS IN MISSOURI'S OLD LEAD BELT (μg/g)

Vegetable	Low	High	Mean	No. of Samples
Lettuce Root	11.7	492.0	68.8	30
Lettuce Leaf	10.3	742.0	83.8	30
Radish Root	5.0	518.0	33.4	30
Radish Top	5.0	117.0	76.7	30
Green Bean Root	5.0	67.0	8.6	30
Green Bean Pod	5.0	10.1	5.4	30

Source: Hemphill et al., 1973

TABLE 3-15
CADMIUM CONCENTRATIONS OF VEGETABLE CROPS IN MISSOURI'S OLD LEAD BELT (μg/g)

Vegetable	Low	High	Mean	No. of Samples
Lettuce Root	0.5	5.9	1.63	30
Lettuce Leaf	0.5	5.03	1.89	30
Radish Root	0.5	2.00	0.84	30
Radish Top	0.5	4.38	1.30	30
Green Bean Root	0.5	0.66	0.51	30
Green Bean Pod	0.5	1.10	0.70	30

Source: Hemphill et al., 1973

In the Old Lead Belt, most values for lettuce were less than 100 μg/l, and most values for radish were less than 50 μg/l. Samples with high lead content were grown near old mines or had been grown in soils to which dolomite limestone wastes had been applied.

Terrestrial

The tailings piles themselves are relatively sterile, providing no habitat for terrestrial species. A review of the available site studies (Appendix A) does not provide much specific BRMTS data on terrestrial and avian species. Data from a study conducted in the Old Lead Belt reported a mean lead concentration in the muskrat liver of 0.69 ppm wet weight (HSDB, USEPA, 1993). Section 5.5 of this RI outlines a proposed study for on-site terrestrial biota.

Threatened and Endangered Species

The federally listed endangered pink mucket pearly mussel (Lampsilis abrupta) has been found in the Big River downstream from the mine tailings plies and in the Meramec River downstream from the mouth of the Big River. Freshwater mussels (naiades) are benthic animals that usually remain buried in the substrate with only the most posterior margin of the shell and siphons exposed to the water column. Mussels are filter feeders and can accumulate heavy metals from particulate matter from the water.

The following describes the Category 2 (C2) candidate species which may be found in the Big and Meramec rivers. C2 candidate species are those for which USFWS is seeking additional information to determine their biological status; few C2 candidate species are proposed for listing. Candidate species have no legal protection under the Endangered Species Act and are included in this document for planning purposes only.

Naiades that have been categorized as C2 candidate species are the special case (Cumberlandia monodonta), which has been found in the Big River, and the snuffbox (Epioblasma triquetra), scaleshell (Leptodea leptodon), and salamander mussel (Simpsonaias ambigua) which have been found in the Meramec River.

One C2 candidate species of fish, the crystal darter (Ammocrypta asprella), has been found in the Big and Meramec rivers downstream from the mine tailings piles. The crystal darter occurs in open stretches of large, clear streams with low or moderate gradients. It can be found over a bottom of sand or small gravel (USFWS, 1995).

4.0 ANALYSIS OF DATA

As described in Section 3.0, several studies were conducted at the BRMTS between 1992 and 1994. The investigations focussed on the Desloge site tailings and surrounding area but include other locations such as Leadwood, Elvins, and the Big River as well. Most of the data on the nature and extent of metals and associated media has indicated that the tailings are composed of the same material at all BRMTS locations. A complete review of the studies that contain data is presented in Appendix A. Information for this section has relied upon EPA's compilation of data from a variety of EPA-sponsored field investigations and data gathered specifically by the EPA and its contractors. The number of validated samples collected over the years is presented in Table 4-1. Additional information has been collected over the years and has been reviewed. This information is also included in Appendix A and serves primarily in the overall understanding of the sites and the possible uses of the tailings.

TABLE 4-1
VALIDATED SAMPLE QUANTITIES

Sample Type	Number of Samples
Tailings/Chat	648*
Soil	246*
Sediment	52
Groundwater	107
Surface Water	37
Biota	242
Air	49

*Validated samples meet EPA data quality objectives for Level III and IV data. See Section 5.0 of this initial RI.

4.1 Constituents of Potential Concern

Constituents of potential concern (COPCs) are those constituents detected at the BRMTS which have been selected for a detailed, quantitative analysis based on their toxicity, mobility, and frequency of occurrence or level of concentration in an environmental media. COPCs are defined as those constituents present in the environmental media at levels that exceed background concentrations and that may present a risk to human health or the environment. These are the constituents for which analytical data is available for use in fate and transport modeling and risk characterization throughout the baseline risk assessment process. COPCs which remain a concern after baseline risks have been calculated become the constituents of concern.

Many evaluations have been conducted on the BRMTS tailings. As the product of a mining district rich in metal bearing ore, the material from location to location within the BRMTS is consistent. As a result of the consistency, the initial selection of COPCs has focused on the analytical information from the tailings. This summer, the MDOH/ATSDR study of blood lead levels, which will include sampling of soil and drinking water, will be conducted for 300 residents around the BRMTS. Upon completion of this program, the results will be incorporated into the RI, and the COPCs may be revisited.

The selection of COPCs for this initial RI was based on data developed primarily through a series of sampling efforts by the EPA and its contractors. Additionally, a recent review of the EPA data by the ATSDR and the state of Missouri (ATSDR, 1994) was incorporated. The RI selection process included a critical review of site data characterizing the tailings, soils, groundwater, surface water, and sediments within the Old Lead Belt study areas. The data sets which were included in this analysis appear in Appendix A.

The EPA National Priorities List (NPL) Addition Announcement (Federal Register, 1991) which placed the Desloge Big River Mine Tailings site on the NPL stated that contaminated tailings and affected soil contain significant amounts of lead, cadmium, and zinc. These metals are also considered to be of primary concern in the EPA site characterization study reports, which supported the site's NPL listing. The purpose of the COPC selection process for this initial RI was to verify, confirm, and if necessary, add to the list of substances of concern at the BRMTS.

As described below, this process started with the complete spectrum of 24 metals analyzed in the BRMTS tailings samples. This procedure was designed to ensure that all 24 metals were considered and evaluated. In addition, the discussions at the Biological Technical Assistance Group (BTAG) meeting on March 1, 1995, have been incorporated.

The COPCs for this initial RI were selected using the five-step process shown in Table 4-2. This process includes:

1. Determination of metals tested in the tailings (samples were analyzed for 24 metals)
2. Determination of detected "hits" for those metals (17 metals were detected)
3. Removal of nutrients (10 metals remain)
4. Comparison of concentrations to national background levels (5 metals remain)
5. Toxicity Evaluation (3 metals remain)

A review of the COPCs selected for this initial RI appears in Table 4-3, and toxicological considerations appear in Section 4.5. Statistical analyses measured and compared on-site concentrations of each detected constituent to background levels and the maximum concentrations of the same constituent in the same media. Constituents whose concentration levels were less than background levels were eliminated. In the toxicological screening, each constituent detected above background (cadmium, cobalt, copper, lead, and zinc) in the tailings was compared to conservative toxicological screening criteria, including risk-based screening values from the EPA's Draft Soil Screening Guidance (EPA, 1994). Laboratory contaminants (identified during data validation), essential micronutrient and macronutrients (calcium, magnesium, and manganese) and ubiquitous minerals (silicon, chlorine, etc.) were excluded. Constituents with <u>no</u> data from the EPA's Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST, 1994) were excluded from quantification in this initial RI.

Table 4-4 summarizes the identified BRMTS COPCs. It is understood that the nature of the tailings at the individual sites is similar, and therefore metals identified at one site would be the same as at the others. The results of application of the COPC selection process to each medium at each site are shown in Table 4-5.

TABLE 4-2
COPC SCREENING PROCESS

Step 1: Metals Tested in Tailings Piles (24)

As	Co	Ni
Ag	Cr	P
Al	Cu	Pb
B	Fe	Sr
Ba	Li	Ti
Be	Mg	V
Ca	Mn	Zn
Cd	Mo	K

Step 2: Metals Detected[a](17)

Al	Cu	P
As	Fe	Pb
Ba	Mg	Sr
Ca	Mn	Zn
Cd	Na	K
Co	Ni	

Step 3: Nutrients Removed[b] (10 remain)

Al	Ba
As	Ni
Cd	Pb
Co	Sr
Cu	Zn

Step 4: Remove Metals at or below National Background[c] (5 remain)

Cd	Cu	Zn
Co	Pb	

Step 5: Remove Metals based on Toxicity (3 remain)

Cd	Pb	Zn

[a] Novak et al. 1980
[b] EPA,1990
[c] Dragun, 1988

TABLE 4-3
COMPARISON OF METAL CONCENTRATIONS SCREENING CRITERIA

Detected Metal	Background Concentration[a] (mg/kg)	Mean Concentration[d] (mg/kg)	Maximum Concentration[c] (mg/kg)	Cancer Slope Factor[d]		Chronic Reference Dose[d]		EPA Soil Screening Level[e]	EPA Soil Screening Level[e]
				Oral $(mg/kg/day)^{-1}$	Inhalation $(mg/kg/day)^{-1}$	Oral (mg/kg/day)	Inhalation (mg/kg/day)	Inhalation (mg/kg)	Ingestion (mg/kg)
Aluminum	100,000 - 300,000	NA	11,000	ND	ND	ND	ND	ND	ND
Arsenic	1.0 - 40	7.6	22	1.8×10^{0}	1.5×10^{1}	3×10^{-4}	ND	380	0.4
Barium	100 - 3,500	NA	930	ND	ND	7×10^{-2}	1.4×10^{4}	350,000	5,500
Cadmium	0.01 - 7.0	21.7	200	ND	6.3×10^{0}	1×10^{-3}	ND	39	920
Cobalt	1.0 - 40	15.4	140	ND	ND	ND	ND	ND	ND
Copper	2 - 100	NA	110,000	ND	ND	ND	ND	ND	ND
Manganese (Food)	100 - 4,000	NA	5,400	ND	ND	1.4×10^{-1}	1.4×10^{-5}	ND	ND
Nickel	50 - 1,000	15.8	140	ND	8.4×10^{-1}	2×10^{-2}	ND	6,900	1,600
Lead (Inorganic)	2 - 200	2,215	17,000	ND	ND	ND	ND		400
Strontium (Stable)	50 - 1,000	NA	36	ND	ND	6×10^{-1}	ND	ND	ND
Zinc	10-300	1,044	63,000	ND	ND	3×10^{-1}	ND	ND	23,000

Notes:
[a] National average background concentrations extracted from Dragun, 1988.
[b] EPA, 1992
[c] Maximum concentrations from EPA LSI, 1991 (see Section 3.0 of this initial RI).
[d] All cancer slope factors and chronic reference doses are from IRIS (EPA, 1994, 1995) or HEAST (EPA 1994), except where noted in other footnotes.
[e] EPA Draft Soil Screening Guidance, December 1994.
NA = Not available

TABLE 4-4
COPCs AND MEAN CONCENTRATIONS (mg/kg)

COPC	MEAN CONCENTRATION
Lead	2215
Cadmium	21.7
Zinc	1044

TABLE 4-5
COPCs FOUND IN ENVIRONMENTAL MEDIA

COPC	Air	Soils	Surface Water	Waste Piles	Sediments	Ground Water	Biota
Lead	X	X	X	X	X	X	X
Cadmium	X	X	X	X	X	X	X
Zinc	X	X	X	X	X	X	X

A discussion of the three COPCs (lead, cadmium, and zinc), their characteristics, potential hazards, and relevant EPA maximum contaminant levels (MCLs) (EPA, 1992) is presented below.

Lead

Lead exists in nature mainly as lead sulfide (galena). Other common forms are lead carbonate (cercissite), lead sulfate (anglesite), and lead chlorophosphates (pyromorphite). Stable complexes result from the interaction of lead with the sulfhydryl, carboxyl, and amine coordination sites found in living matter. The toxicity of lead in water is affected by pH, hardness, organic materials, and the presence of other metals. The aqueous solubility of lead ranges from 3 μg/l in hard water to 500 μg/l in soft water (EPA, 1992).

Lead accumulates in the tissue of humans and other animals. Although seldom seen in the adult population, irreversible brain damage is a frequent result of lead intoxication in children. This most commonly results from the ingestion of lead-containing paint found in older homes. The major toxic effects of lead include anemia, neurological dysfunction, and renal impairment.

The most common symptoms of lead poisoning, which usually develop slowly, are anemia, sever intestinal cramps, paralysis of nerves (especially the arms and legs), loss of appetite and fatigue. The current action level for lead in drinking water is 50 μg/l; the proposed action level is 0.015 mg/l (if exceeded in more than 10 percent of tap-water samples collected during any monitoring period). The national Ambient Air Quality Primary Standard for lead in the air in a calendar quarter is 1.5 $\mu g/m^3$ (EPA, 1992).

Cadmium

Cadmium occurs mainly as a sulfide salt, frequently in association with zinc and lead ores. Accumulation of cadmium in soils in the vicinity of mines and smelters may result in high local concentrations in nearby waters. Cadmium is deposited and accumulated in various body tissues. It may function in or may be an etiological factor for various human pathological processes including testicular tumor, renal dysfunctions, hypertension, arteriosclerosis, growth inhibition, chronic diseases of old age, and cancer. The current MCL for cadmium in drinking water is 10 μg/l; the proposed MCL is 5 μg/l (EPA, 1991 and 1992 and Missouri 10 CSR 60-4, 1994).

Zinc

Zinc is usually found naturally as a sulfide, and it is often associated with other metals, especially lead, copper, cadmium, and iron. It is used in galvanizing processes and in preparation of alloys. Zinc is essential and beneficial in human metabolism. Community water supplies tested have contained 11 to 27 mg/l without harmful effects. The toxicity of zinc compounds to aquatic animals is modified by environmental factors. An increase in temperature and reduction in dissolved oxygen increases the toxicity of zinc for fish. Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of fish. No primary MCL for zinc has been established (EPA, 1992).

4.2 COPC Sources

Lead, cadmium, and zinc have been detected in the tailings, surface water, groundwater and air, and in vegetation, aquatic species, and wildlife. The elevated levels of lead, zinc, and cadmium in each environmental media reflect the nature of the region, which attracted mining from the 1700s, and indicates locally elevated levels of lead. The COPCs were selected primarily based on the contents and consistency of the tailings, characteristic of which is windborn dust and surface water erosion. The MDOH (with funding from The Doe Run Company) will collect field sample data this summer to supplement information on lead levels for 300 homes in the vicinity of the BRMTS. This field sampling and analysis program will yield surface soil lead concentrations around homes and back yards, drinking water lead levels, interior house dust analysis, and house paint lead content. In addition, blood-lead levels will be determined for children. The results of the MDOH program will be incorporated into this RI, and the direction for further testing of soils, drinking water, and blood, if necessary, will be addressed at that time. At this stage of the RI, the focus is on the tailings and information gathered to date or needed in the future so that the wind erosion and surface water erosion of the tailings can be controlled. The sources of COPCs would include the current and former locations of the tailings.

TABLE 4-6
CHAT PILE AND TAILINGS POND ACREAGE

Site	Chat Pile Acres	Tailings Pond Acres
National	44	108
Elvins	72	77
Bonne Terre	39	306
Doe Run	9	0
Hayden Creek	0	0
Federal	43	1005
Desloge	95	275
Leadwood	35	528

Source: Sears, 1985

* Validated samples meet EPA data quality objectives for Level III and IV data. See Section 5.0 of this initial RI.

Desloge Site

In December 1977, the Desloge area experienced severe rainfall that caused a portion of the tailings to collapse into the Big River. It has been reported by EPA that the mine tailings located at the site cover over 500 acres. Tailings on the site range from 0 to 100 feet deep with an average depth of 50 feet and contain elevated amounts of lead, cadmium, and zinc. The tailings are eroding and are being transported into the river, ambient air, and possibly the groundwater. The EPA considers the metals lead, cadmium and zinc as the primary concern. Toxicity profiles for these metals appear in Section 4.5.

The tailings have been estimated to cover approximately 95 acres. The average thickness of the tailings is approximately 46 feet based on an evaluation of contours from a 1908 USGS map (before tailings deposition) compared to current elevations. Well logs also verify that the tailings are less than approximately 50 feet thick. Therefore, the overall volume of waste at Desloge is calculated at approximately 6,500,000 cubic yards. Efforts to provide short- and long-term stabilization of the tailings have included snow fences, grass seeding, and planting Black Locust trees (MDOH, 1994). A landfill and landfill office are located on the south end of the site.

National Site

The National site covers 175 acres and is located 1.37 miles from the Big River. The estimated tailings volume is 6,400,000 cubic yards based on a 44-acre pile. There is a north erosion area, an east erosion area, and the main tailings pile. The mean concentrations in the main tailings are 3,508 μg/g for lead, 7.2 μg/g for cadmium, and 457 μg/g for zinc. The maximum concentrations are 9,283 μg/g for lead, 87 μg/g for cadmium, and 5,055 μg/g for zinc.

The mean concentrations in the tailings at the north erosion area are 2,510 μg/g for lead, 4.9 μg/g for cadmium, and 112 μg/g for zinc. The mean concentrations in the tailings at the east erosion area are 6,894 μg/g for lead, 6.4 μg/g for cadmium, and 295 μg/g for zinc.

Leadwood Site

The Leadwood site area is 528 acres and is located 0.86 miles from the Big River. The estimated volume of tailings is 5,100,000 cubic yards. The mean concentrations in the tailings are 2,444 μg/g for lead, 267 μg/g for cadmium, and 5,009 μg/g for zinc. The maximum concentrations are 17,000 μg/g for lead, 1,870 μg/g for cadmium, and 25,800 μg/g for zinc.

Elvins/Rivermines Site

The Elvins site covers 149 acres and is located 1.74 miles from the Big River. The volume of mine tailings is 10,400,000 cubic yards. The mean concentrations in the tailings are 4,392 μg/g for lead, 103 μg/g for cadmium, and 5,482 μg/g for zinc. The maximum concentrations are 11,600 μg/g for lead, 202 μg/g for cadmium, and 11,900 μg/g for zinc.

Bonne Terre Site

The Bonne Terre site covers 300 acres and consists of two tracts located 1.18 miles from the Big River. One tract located east of Highway 67 has 295 acres of dry and water-covered tailings. The other tract, west of Highway 67, is estimated to contain 5,700,000 cubic yards. The mean concentrations in the tailings pile are 3,515 μg/g for lead, 13.9 μg/g for cadmium, and 541 μg/g for zinc. The maximum concentrations are 7,010 μg/g for lead, 29.5 μg/g for cadmium, and 967 μg/g for zinc.

Federal Site

The Federal site consists of a 1,005 acre tailings pond, 43 acres of development rock, and 15 acres of tailings/disposal areas. It is located 2.72 miles from the Big River. The tailings is 43 acres and has a volume of mine tailings estimated at 6,200,000 cubic yards. The range of concentrations for lead in the tailings is 508 to 2,830 μg/g; data for cadmium and zinc was not available (ATSDR, 1994).

Doe Run Site

The tailings site at Doe Run have been removed. The foot print of residual materials from the tailings is 9 acres. Doe Run is 9.35 miles from the Big River.

Hayden Creek Site

Hayden Creek was a mine with limited processing facilities and is now a farm. The mined ore was sent to Leadwood for processing. Materials that remain at Hayden Creek would include potential residual COPCs and development rock piles. No tailings are evident. Hayden Creek is located 0.71 miles from the Big River.

Big River Sediments

Concentrations of lead, cadmium, and zinc in the Big River are generally below the drinking water standard for lead (0.05 mg/l), cadmium (0.005 mg/l), and zinc (5 mg/l). This is consistent with the known limited solubility of lead compounds in hard alkaline waters. During a large storm in 1977, an estimated 50,000 cubic yards of the Desloge tailings were released to the Big River. Sediment from the release and continued erosional and drainage releases have added to the concentrations of lead, cadmium, and zinc in the Big River.

The affected area was considered to be 50 miles long, from Leadwood downstream to Mammoth Access. The MDOH now recommends that carp, should not be eaten if taken from the Big River downstream of Desloge to where it enters the Meramec River. The warning is generally known by local fishermen (MDOH,1994).

4.3 Extent of COPCs

Since the initial spill into the Big River in 1977, the EPA and the state of Missouri (MDOH and MDNR) have assembled a history of the Old Lead Belt. In addition, a series of investigations have been conducted throughout the Old Lead Belt and with a specific focus on Desloge and its immediate surroundings. The tailings at Desloge are well characterized. Erosion of the tailings from wind and storm water, cutting from the river bank, and disturbance from human activities or animals entrain the tailings in environmental media and facilitate transport through exposure pathways. Several monitoring studies of surface water, air, soils, groundwater, sediments, and biota have been conducted on- and-off site.

The following section considers the Desloge site in greater detail as it is indicative of the area-wide tailings.

Quantity of COPCs

The lead at the BRMTS is a result of 30 years of stockpiling mine tailings. Tailings cover approximately 95 acres and may be as much as 50 feet deep. The highest detected lead concentration of tailings at the site is 13,000 mg/kg, while the average concentrate is 2215 mg/kg. Cadmium and zinc have also been detected in tailings samples from the site at maximum concentrations of 270 mg/kg and 13,000 mg/kg, respectively. Site averages for cadmium and zinc are 21.7 and 1,044 mg/kg, respectively. As noted, the primary COPC at the site is lead (EPA 1993a). It is postulated that analyses and actions to contain lead would also contain the other metals detected and that lead is the driving COPC.

Release of COPCs

Some industrially produced lead compounds are readily soluble in water. However, metallic lead and the common lead minerals are relatively insoluble in water. Natural compounds of lead are not particularly mobile in normal surface water or groundwater since the lead leached from ores is adsorbed by ferric hydroxide or combines with carbonate or sulfate ions to form insoluble compounds (EPA, 1993a). Movement of the lead and its inorganic and organic lead compounds as particulate in the atmosphere is a major environmental transport process. The transport of lead in the aquatic environment is influenced by the speciation of the lead ion. Lead exists mainly as the divalent cation in most unpolluted waters and becomes adsorbed into particulate phases. In waters with more chemical elements or organic compounds, the organic complexation is more important (EPA, 1993.)

Adsorption to inorganic solids, organic materials, and hydrous iron and manganese oxides usually controls the mobility of lead, resulting in strong partitioning of lead to the bed sediments in aquatic systems. The sorption mechanism most important in a particular system varies with geological setting, pH, availability of ligands, dissolved and particulate ion concentrations, salinity, and chemical composition. The equilibrium solubility with carbonate, sulfate, and sulfite is low. Over most of the normal pH range, lead carbonate and lead sulfate control the solubility of lead in aerobic conditions, while lead sulfite and metal control the solubility in anaerobic conditions. Lead is strongly complexed to organic materials present in aquatic systems and soil.

Lead in soil is not easily taken up by plants; therefore, its availability to terrestrial organisms through ingestion is somewhat limited (EPA, 1993a).

Transport of lead-bearing tailings from the site occurs via four main natural transport processes: wind erosion, bank erosion, storm water runoff, and leachate (EPA, 1993a). Tailings in the sediments of the Big River may resuspend and transport down river.

Dispersal of tailings particulate through the air is a significant transport mechanism. The tailings are lead-laden dolomitic sand and silt, which is easily suspended in the air and carried off site. Volumes of tailings particulate have been documented to travel from the site to the town of Desloge. Analytical results of air samples collected on site and at nearby residences show off-site transport of lead-laden particulate (EPA, 1993a). Various studies conducted by the state of Missouri and EPA indicate that primarily total suspended particulate (TSP) in air was measured and not inhalable sized fractions commonly known as PM10.

The areas at the Desloge site that are most likely to be a source of airborne particulate are the dry and unvegetated tailings areas. Of the 540-acre area (600 acres minus the 60-acre sanitary landfill), the area of dry and unvegetated tailings pond is approximately 275 acres on top of the site and approximately 45 acres on the slopes.

In addition to wind erosion, bank erosion along the perimeter of the site is of concern. As previously described, bank sloughing has occurred at the Desloge site, with tailings material transported directly into the Big River.

Tailings are transported into the Big River by surface runoff. A drainage tunnel (approximately 12 feet wide, 10 feet high, and 1,500 feet long) originates approximately 300 feet southeast of the landfill office. This drainage tunnel was built by St. Joe Minerals to divert surface water from a tributary to the Big River. The tributary has been filled with tailings. Because landfill operators had a problem with standing water in an area approximately 200 feet north of the tunnel entrance, a culvert was installed under the access road to drain water from this low-lying area to the drainage tunnel and eventually to the Big River (EPA, 1993a).

The presence of the landfill and acidic leachate from the landfill present a possible vehicle for extracting lead to the groundwater at the Desloge site. Analytical results indicate lead in on-site monitoring wells in the shallow aquifer. One of the local aquifers, the Bonne Terre formation, is dolomitic, and thus the groundwater is alkaline. Lead normally has limited solubility in alkaline water, reducing the potential for lead contamination of groundwater. The significance of lead from tailings via groundwater flow needs to be evaluated further, after the drinking water data gathered by MDOH for the 300 homes becomes available this summer (EPA, 1993a).

Applicable or Relevant and Appropriate Requirements

A preliminary list of applicable or relevant and appropriate requirements (ARARs) which EPA identified for federal and state sites is presented in Table 4-7.

TABLE 4-7
ARARs

ARAR	Source
National Ambient Air Quality Standards	Clean Air Act 42 U.S.C. Sections 7401 et.seq., 40 CFR Part 250 and 10 CSR 10-6.010.
Fugitive Particulate Matter Regulations	10 CSR 10-6170
Sediment Control Measures	30 CFR Part 816.45
Siltation Structures	30 CFR Part 816.46
Grading Requirements	30 CFR Part 816.102
Revegetation Requirements	30 CFR Part 816.111
Clean Water Act	Section 301(b) and CSR 20-7/0150 and 10 CSR 20-7031
Storm Water Requirements	10CSR 20-6.200
Protection of Flood Plains	Executive Order 11990 and 40 CFR Part 6 Appendix A
RCRA Subtitle D	40 CFR Part 257

Other criteria to be considered:
State of Missouri Metallic Minerals Act
EPA/OSWER Interim Guidance on Soil Cleanup Levels
CSR = Code of State Regulation (Missouri)
Source: EPA, 1993

4.4 Transport Mechanisms

In this section, the physical and chemical properties which affect chemical fate and transport in the environment are presented. Transport mechanisms specific to the BRMTS COPCs are discussed.

Physical and Chemical Properties Affecting Fate and Transport

To evaluate the fate and transport of a COPC, the chemical and physical properties of the constituent and the surrounding environment need to be evaluated. Chief factors considered include constituent mobility, persistence, and stability. Additional factors, such as the physical, chemical, and biological processes that may affect a constituent, are also considered. The following is a brief list of key factors or processes, COPC or chemical characteristics, and environmental conditions that may influence the chemical fate and transport of an inorganic constituent:

- Chemical Factors
  - Organic and inorganic content of the soils
  - Electrical conductivity, cation and anion concentration, and pH
  - Chemical processes, e.g., hydrolysis, acid-based reactions, redox reactions, and ion pairing or complexes

- Biological Factors
  - Populations of microorganisms in soils
  - Aerobic and anaerobic microbiological processes

- Physical Factors
  - Wind erosion
  - Bank erosion
  - Storm water run-off
  - Leachate
  - Sediment resuspension and movement

Physical and chemical parameters which affect the transport and fate of COPCs at the BRMTS include water solubility, specific gravity, partition coefficient, particle size and inhalable size fraction of the tailings, and fish bioconcentration factor. The solubility of a constituent in water is the maximum or saturated concentration of the constituent in pure water at a specific temperature. Specific gravity is the ratio of the density of a constituent to the density of water. The fish bioconcentration factor (BCF) is a measure of the tendency for a constituent present in water to accumulate in fish tissue.

The fate and transport properties of different constituents vary based on degree of persistence, physical and chemical properties such as solubility or volatility, and whether or not the constituent can be degraded. The fate and transport mechanisms usually considered are photolysis, oxidation, hydrolysis, volatilization, sorption, bioaccumulation, and biotransformation/ biodegradation. Photolysis is the process in which certain constituents break down into smaller molecules in the presence of light. In oxidation, a constituent gains an oxygen atom or loses a hydrogen atom while losing an electron or simply loses an electron. Oxidation and reduction always occur simultaneously, with the electron lost by one reactant being transferred to another reactant (a redox reaction). Hydrolysis is the splitting of a constituent molecule into two fragments through reaction with a water molecule. Sorption is a term that designates processes that remove a constituent from the aqueous environment by binding the constituent in soil particles or in a separate liquid phase. Bioaccumulation is defined as the process in which living organisms retain constituents in their tissues. Biodegradation describes biological changes of organic constituents. Biotransformation describes biological changes of organic constituents into inorganic constituents (EPA, 1989a).

COPCs

The geochemistry of a site can be influenced by the fate and transport of inorganic constituents present at the site. The chemical variables which are primarily responsible for controlling metal speciation (the form of the molecule or ion in solution) are the electrode potential (Eh) and acidity/basicity (pH) (EPA, 1989a). Eh is a measure of the electrochemical potential of the ions present in either soil or water and determines the oxidation state of a metal; pH is a measure of acidity or alkalinity of the media and determines whether a metal, in a given oxidation state, is present as a charged ion or is associated with an anion(s). Metals may occur as aqueous species or may precipitate out of solution. The pH and Eh in water or soil at a site affect the degree with which the following mechanisms attenuate metals: adsorption by soil, particularly clays in solid media and colloids in solution; precipitation or coprecipitation; adsorption to iron and manganese oxides; complexation with organic matter and ion exchange. As noted, the COPCs at the BRMTS include lead, cadmium, and zinc.

Air

Tailings from past mining operations were deposited on the ground and piled as high as 100 feet at the Desloge site. The tailings contain heavy metals. Part of the tailings are powdery, so the material is carried as particulate through the air when wind or human activity (such as off-road vehicle use) disturb the tailings. Strong winds have reportedly carried clouds of dust from the tailings as far as one mile (MDOH, 1994)

The several sets of tailings in St. Francois County complicates the determination of how much airborne particulate is contributed by any one source. Data from the air monitoring study at Desloge would be indicative of the amount of blowing dust at other sites.

Indoor Dust

When particulate from the sites become airborne, it can enter nearby buildings and be entrained in the indoor air. The collection of vacuum cleaner dust from the area in 1985 by DOH supports this theory. Persons living in the homes near the tailings are exposed to indoor dust. Air monitoring conducted at various times by EPA's field investigation team has documented lead, cadmium, and zinc in the air samples. When high-volume air sample results were compared to the TSP standard of 260 $\mu g/m^3$ and the ambient lead standard of 1.5 $\mu g/m^3$, the results indicated that both the TSP and lead were below the National Ambient Air Quality Standards (NAAQS).

Soils

Tailings are transported by wind and stormwater erosion to soils on- and off-site. COPCs can possibly migrate from the top six inches of surface soil to greater depth due to water percolation through the soils.

Groundwater

The presence of the landfill and acidic leachate from the landfill present a possible vehicle for extracting lead to the groundwater at the Desloge site. Analytical results indicate lead in on-site monitoring wells in the shallow aquifer. One of the local aquifers, the Bonne Terre formation, is dolomitic, and thus the groundwater is alkaline. Lead normally has limited solubility in alkaline water, reducing the potential for lead contamination of groundwater. The significance of lead from tailings via groundwater flow needs to be evaluated further based upon the field sampling efforts planned this summer (EPA 1993a).

Surface Water and Sediment

Tailings are transported into the Big River via surface runoff. A drainage tunnel (approximately 12 feet wide, 10 feet high, and 1,500 feet long) originates approximately 300 feet southeast of the landfill office at Desloge. This drainage tunnel was built by St. Joe Minerals to divert surface water from a tributary to the Big River. The tributary has been filled with tailings. Because landfill operators had a problem with standing water in an area approximately 200 feet north of the tunnel entrance, a culvert was installed under the access road to drain from this low-lying area to the drainage tunnel and eventually to the Big River (EPA, 1993a).

In a study conducted by the National Fisheries Research Laboratory (NFRL), the metals content in river water and sediment was measured at different locations along the Big River. The Irondale and Mineral Fork sampling locations were considered control areas; Desloge, Washington State Park, and Brown's Ford are 5 miles, 37 miles, and 60 miles, respectively, downstream from the Desloge tailings. Water sampling was done during low, medium, and high stream flow. Total metals and dissolved metals were measured for lead, cadmium, and zinc. The highest total lead (0.68 mg/l) occurred at Washington State Park, and the highest dissolved lead (0.026 mg/l) occurred at Brown's Ford. Lead concentrations in the Big River ranged from 0.041 to 0.110 mg/l. Cadmium ranged from 0.001 to 0.004 mg/l. Zinc ranged from 0.11 to 0.036 mg/l.

Sediment samples were collected from corresponding locations on the Big River. Sediment total lead concentrations were highest in Desloge (2215.0 mg/kg) and tended to decrease with distance downstream. This value is similar to the total lead content found in the tailings at the Desloge site. Total lead concentration was lowest (49.6 mg/kg) at Irondale. Concentrations at Mineral Fork were substantially higher than at Irondale, though they were lower at Mineral Fork than at other locations. This is probably attributable to the past lead mining or ongoing barite mining activities in the Mineral Fork watershed. These sampling results indicate how the mine tailings had affected the benthic zone of the Big River at the Desloge site and for several miles downstream.

Biota

Aquatic and terrestrial biota have concentrations of lead, cadmium, and zinc from ingestion of soils and sediments, benthic organisms, and from ingestion of smaller biota with body burdens of the COPCs. The bioavailablity of the COPCs from water ingestion and adsorption is not significant.

Crops

Investigations by the EPA and the University of Missouri indicate COPCs are present in vegetation and livestock. COPCs in soils, deposited as dust, and uptake through plant roots and leaves account for the movement of COPCs in crops.

4.5 Toxicological Assessment of COPCs

The toxicity assessment in this section contains a compilation of toxic and carcinogenic effects of the BRMTS COPCs, followed by detailed evaluations of those COPCs. This section presents tabulated summary toxicity information of noncarcinogenic and carcinogenic effects. The primary sources of information for this section are:

- EPA's Integrated Risk Information System (IRIS) on-line database (EPA, 1994 and 1995).
- EPA's Health Effects Assessment Summary Tables (HEAST) annual report (EPA, 1994).

Noncarcinogens

Reference doses (RfDs) and dose-response data for noncarcinogenic effects associated with exposure to the COPCs were previously presented in Table 4-2. Since the RfD is usually based on data from exposure studies using animal models, an uncertainty factor has been incorporated to provide a safety factor for the extrapolation from animals to humans. When available, RfDs for both the ingestion and inhalation pathways are presented. The sources for reference dose values and dose-response data were the IRIS database (EPA, 1994 and 1995) and HEAST which are compiled and maintained by EPA (1994b). IRIS was used as the primary source for toxicity information. HEAST was used only if IRIS values were unavailable (EPA 1989a).

Carcinogens

The incremental lifetime cancer risk (ILCR) due to exposure to a chemical can be calculated as the product of the lifetime chronic daily intake (mg/kg/day) and the cancer slope factor of that chemical. The carcinogenic slope factor values (Table 4-2) came entirely from EPA sources (IRIS and HEAST) and were defined by EPA's Carcinogen Assessment Group (CAG).

In developing the cancer slope factors, the EPA gave preference to human epidemiology studies; however, the slope factors for most chemicals were in fact derived from animal exposure studies. An inherent assumption in the EPA's approach is that there is no threshold for a carcinogenic effect. That is, smaller doses result in smaller risks, but any dose, no matter how small, carries some risk. The dose-related number of tumors and the time of incidence of tumors were fitted using a linear multi-stage model. A slope factor describing the linear relationship of lifetime risk to dose was computed using the 95 percent upper confidence limit (UCL) of this slope. This approach is inherently conservative because of the no-threshold assumption and the use of the 95 percent UCL.

Cadmium

Pharmacokinetics

Gastrointestinal absorption of ingested cadmium is ordinarily 5 to 8 percent, but may reach 20 percent in cases of serious dietary iron deficiency (Friberg et al. 1986a; Goyer 1991). EPA

(1993b) recommends use of a gastrointestinal absorption factor of 0.025. Data regarding dermal absorption of cadmium was not located.

Estimates of cadmium uptake by the respiratory tract range from 10 to 50 percent; uptake is greatest for fumes and small particles and least for large dust particles (Friberg et al. 1986a; Goyer 1991). Highest tissue levels are normally found in the kidneys followed by the liver, although levels in the liver may exceed those in the kidneys of persons suffering from cadmium-induced renal dysfunction. The half-life of cadmium in the kidneys and liver may be as long as 10 to 30 years. Fecal and urinary excretion of cadmium are approximately equivalent in normal humans exposed to small amounts. Urinary excretion increases markedly in humans with cadmium-induced renal disease.

Noncarcinogenic Toxicity

The EPA (1991a) has presented verified chronic oral RfD values of 0.0005 mg/kg/day for cadmium ingested in water and 0.001 mg/kg/day for cadmium ingested in food. Medium-specific oral RfD values reflected the assumption that cadmium is more efficiently absorbed from water than from food. The RfD values were based on a NOAEL for proteinuria (a sensitive indicator of renal toxicity), determined from several human exposure studies. Occupational exposure to fumes of cadmium induced metal fume fever (ACGIH 1991). The principal target organs for oral exposure to cadmium are the kidneys.

Carcinogenicity

Cadmium is classified as an EPA cancer weight-of-evidence Group B1 substance (probable human carcinogen), based on limited evidence from occupational studies and sufficient evidence of carcinogenicity in rats and mice following inhalation exposure or parenteral injection (EPA 1991a). There is insufficient information to classify cadmium as carcinogenic to humans by the oral route. A provisional inhalation slope factor of 6.3 per mg/kg/day and a unit risk of 0.0018 per $\mu g/m^3$ (based on a person inhaling 20 cubic meters of air per day and weighing 70 kilograms) was based on the incidence of lung cancer in cadmium smelter workers.

Lead

Pharmacokinetics

Studies in humans indicate that an average of 10 percent of ingested lead is absorbed, but estimates as high as 40 percent were obtained in some individuals (Tsuchiya 1986). Nutritional factors have a profound effect on gastrointestinal absorption efficiency. Children absorb ingested lead more efficiently than adults; absorption efficiencies up to 53 percent were recorded for children 3 months to 8 years of age. Similar results were obtained for laboratory animals; absorption efficiencies of 5 to 10 percent were obtained for adults and ≥50 percent were obtained for young animals. The deposition rate of inhaled lead averages approximately 30 to 50 percent, depending on particle size, with as much as 60 percent deposition of very small particles (0.03 μm) near highways. All lead deposited in the lungs is eventually absorbed.

Approximately 95 percent of the lead in the blood is located in the erythrocytes (EPA 1990a). Lead in the plasma exchanges with several body compartments, including the internal organs, bone, and several excretory pathways. In humans, lead concentrations in bone increase with age (Tsuchiya 1986). About 90 percent of the body burden of lead is located in the skeleton. Neonatal blood concentrations are about 85 percent of maternal concentrations (EPA 1990b). Excretion of absorbed lead is principally through the urine, although gastrointestinal secretion, binary excretion, and loss through hair, nails, and sweat are also significant.

Noncarcinogenic Toxicity

The noncarcinogenic toxicity of lead has been well characterized through decades of medical observation and scientific research (EPA 1993b). The primary effects of long-term exposure to levels expected to be encountered in the environment are neurological and hematological. Some of the effects on the blood, particularly changes in levels of certain blood enzymes, and subtle neurobehavioral changes in children appear to occur at levels so low as to be considered nonthreshold effects. In part for this reason the RfD/RfC Work Group considered inappropriate the derivation of an RfC or RfD for inhalation exposure, or an RfD for oral exposure (EPA 1993b). The principal target organs of lead are the central nervous system and the hematopoietic system.

Bioaccumulation

Lead readily bioaccumulates in aquatic species. However, there is no evidence that it is transferred through food chains (Eisler, 1988). This is demonstrated in aquatic food chains where lead concentrations tend to decrease with increasing trophic levels (Eisler, 1988). Bioconcentration factors (BCFs) for freshwater species range from 42 to 45 for brook trout and bluegill, respectively. BCFs for saltwater vivalve mollusks range from 17.5 to 2,570 for the quahog clam and blue mussel, respectively (EPA, 1985b). Lead has a tendency to form compounds of low solubility with major anions found in water (ATSDR, 1991). Biomethylation of lead by benthic microorganisms can lead to its mobilization and reintroduction into the aqueous environment (HSDB, 1994). Plants may uptake lead from soil (ATSDR, 1991). Lead is readily metabolized in and excreted by terrestrial organisms but is accumulated in bones and feathers at higher concentrations than in other tissues (Eisler, 1988).

Lead is recognized as being toxic to aquatic organisms, birds, mammals, among others. Its toxic action in aquatic species varies with species and with physical and chemical environmental variables (Eisler, 1988). Water-soluble lead is more toxic to aquatic organisms than total lead (Eisler, 1988), and increased hardness decreases the toxicity of lead in fresh water systems (EPA, 1985). In aquatic organisms, lead is teratogenic and causes reproduction impairment. Lead causes hematological, neurological, renal, reproductive, and teratogenic effects in terrestrial organisms (ATSDR, 1991). Adverse effects could potentially be seen in organisms exposed to lead in abiotic media, and in prey organisms that have bioaccumulated lead. The accumulated lead may not be readily bioavailable, however, since lead tends to be sequestered in bone and feathers that likely are not eaten or digested.

The EPA has developed an uptake/biokinetic model to predict blood-lead levels in populations exposed to lead in air, diet, drinking water, indoor dust, soil and paint. This makes it possible to evaluate the effects of regulatory decisions concerning each medium on blood-lead levels and potential health effects. The model is used to estimate lead uptake and subsequent blood-lead levels in young children, who are the most sensitive subpopulation for exposure to lead. It accepts user input of variables pertaining to site-specific exposure to lead through air, diet, water, soil, dust, and paint (EPA 1990b).

OSWER Directive No. 9355.4-12 (EPA 1994) establishes a soil screening level for lead of 400 ppm for residential land use based on the Integrated Exposure Uptake Biokinetic Model. This level is designed to protect children from blood-lead concentrations, which are associated with lead-induced neurological effects.

The soil screening levels are not cleanup goals. Screening levels are meant to be a tool to determine which sites or portion of sites do not require further study. Based on site data and considering other factors such as reliability of institutional controls, technical feasibility, and/or community acceptance, still higher cleanup levels may be selected.

Carcinogenicity

Lead is assigned to cancer weight-of-evidence Group B2 (probable human carcinogen), based on inadequate human evidence but sufficient animal evidence (EPA 1993b). Rat and mouse bioassays have shown statistically significant increases in renal tumors following dietary and subcutaneous exposure to several soluble lead salts. The EPA has declined to quantitatively estimate risk for oral exposure to lead because many factors (i.e., age, general health, nutritional status, existing body burden, and duration of exposure) influence the bioavailability of ingested lead, introducing a great deal of uncertainty into any estimate of risk. In addition, current knowledge of lead pharmacokinetics indicates that an estimate derived by standard procedures would not truly describe the potential risk. Thus, the EPA Carcinogen Assessment Group recommends that a numerical estimate not be used (IRIS; EPA, 1993).

Zinc

Pharmacokinetics

Zinc is a nutritionally required trace element. Estimates of the efficiency of gastrointestinal absorption of zinc in animals range from less than 10 to 90 percent (Elinger 1986). Estimates in normal humans range from approximately 20 to 77 percent (Elinger 1986; Goyer 1991). EPA (1993b) recommends use of a gastrointestinal absorption factor of 0.25. The net absorption of zinc appears to be homeostatically controlled, but it is unclear whether gastrointestinal absorption, intestinal secretion, or both are regulated.

Data regarding respiratory tract or dermal absorption of zinc was not located.

5.0 DATA QUALITY REVIEW

Numerous environmental studies have been conducted throughout Missouri's Old Lead Belt. Samples have been collected and analyzed to evaluate the potential public health and environmental impact from lead mining and production operations. The data from these studies, which varies widely in quality, is evaluated in this section using guidelines established by the EPA in three primary documents:

- Risk Assessment Guidance for Superfund (EPA, 1989)
- Guidance for Data Useability in Risk Assessment (EPA, 1990 and 1992)
- Data Quality Objectives for Remedial Response Activities (EPA, 1987)

5.1 Data Quality Objectives and Summary

In determining the useability of data, the data quality objectives (DQOs) of the site characterization must be reviewed. DQOs are qualitative statements that specify the level of data quality required to support decisions during the remedial response and risk management activities. DQOs are determined by considering the purpose for which the data is collected. Every site has unique features, so DQOs are site specific. DQOs are not static and may change as additional details about the project are discovered.

The RI/FS process represents the methodology that the CERCLA program has established for characterizing the nature and extent of uncontrolled hazardous waste releases. The objective of the RI/FS characterization process is not to remove all uncertainty about the site contamination, but rather to gather information sufficient to support an informed risk management decision. The five levels of analytical data and the applicability of each data level for CERCLA investigations are summarized in Table 5-1.

TABLE 5-1
SUMMARY OF ANALYTICAL LEVELS APPROPRIATE TO DATA USES FOR CERCLA INVESTIGATIONS

Data Uses	Analytical level	Type of Analysis	Limitations	Data quality
• SITE CHARACTERIZATION • MONITORING DURING IMPLEMENTATION	LEVEL I	- TOTAL ORGANIC/INORGANIC VAPOR DETECTION USING PORTABLE INSTRUMENTS - FIELD TEST KITS	- INSTRUMENTS RESPOND TO NATURALLY OCCURRING COMPOUNDS	- IF INSTRUMENTS CALIBRATED AND DATA INTERPRETED CORRECTLY, CAN PROVIDE INDICATION OF CONTAMINATION
• SITE CHARACTERIZATION • EVALUATION OF ALTERNATIVES • ENGINEERING DESIGN • MONITORING DURING IMPLEMENTATION	LEVEL II	- VARIETY OF ORGANICS BY GC; INORGANICS BY AA; XRF - TENTATIVE ID; ANALYTE-SPECIFIC - DETECTION LIMITS VARY FROM LOW ppm TO LOW ppb	- TENTATIVE ID - TECHNIQUES/INSTRUMENTS LIMITED MOSTLY TO VOLATILES, METALS	- DEPENDENT ON QA/QC STEPS EMPLOYED - DATA TYPICALLY REPORTED IN CONCENTRATION RANGES
• RISK ASSESSMENT • SITE CHARACTERIZATION • EVALUATION OF ALTERNATIVES • ENGINEERING DESIGN • MONITORING DURING IMPLEMENTATION	LEVEL III	- ORGANICS/INORGANICS USING EPA PROCEDURES OTHER THAN CLP CAN BE ANALYTE-SPECIFIC - RCRA CHARACTERISTIC TESTS	- TENTATIVE IN SOME CASES - CAN PROVIDE DATA OF SAME QUALITY AS LEVELS IV, NS	- SIMILAR DETECTION LIMITS TO CLP - LESS RIGOROUS QA/QC
• RISK ASSESSMENT • EVALUATION OF ALTERNATIVES • ENGINEERING DESIGN	LEVEL IV	- HSL ORGANICS/INORGANICS BY GC/MS; AA; ICP - LOW ppb DETECTION LIMIT	- TENTATIVE IDENTIFICATION OF NON-HSL PARAMETERS - SOME TIME MAY BE REQUIRED FOR VALIDATION OF PACKAGES	- GOAL IS DATA OF KNOWN QUALITY - RIGOROUS QA/QC
• RISK ASSESSMENT	LEVEL V	- NON-CONVENTIONAL PARAMETERS - METHOD-SPECIFIC DETECTION LIMITS - MODIFICATION OF EXISTING METHODS - APPENDIX 8 PARAMETERS	- MAY REQUIRE METHOD DEVELOPMENT/MODIFICATI ON - MECHANISM TO OBTAIN SERVICES REQUIRES SPECIAL LEAD TIME	- METHOD-SPECIFIC

A brief description of the analytical levels follows:

Level I - Gross field testing, not compound-specific, which provides an indication of contamination.

Level II - Field analysis using more sophisticated field instruments, which provides concentrations or ranges of concentrations of specific compounds.

Level III - Analyses performed in an off-site laboratory which may or may not use Contract Laboratory Program (CLP) procedures. Level III analyses do not usually provide the validation or documentation of Level IV analyses.

Level IV - Routine analyses performed using CLP procedures in an off-site laboratory. Level IV data is characterized by rigorous QA/QC protocols and attendant documentation.

Level V - Analysis performed using nonroutine methods for nonroutine constituents or detection limits, yet employing the same rigorous QA/QC requirements as Level IV protocols.

The appropriate analytical level depends on the intended use of the data. For example, health and safety monitoring typically uses Level 1 data, whereas risk assessment uses data from Levels III through V. Site characterization may uses data from Levels II through IV.

Even though some data historically collected for the BRMTS predates the development of EPA's scheme for classifying the levels of analytical data or the CLP, such data will be classified based on these categories. Key items to be examined include the completeness of documentation for sample collection, i.e., location, depth, time, date, chain of custody, etc. Additional items include analytical methodology, holding times, completeness of documentation, detection limits, and QA/QC employed.

From an analysis of the sample documentation, the suitable use of the data can be sorted into three categories:

1. Nonuseable data. An example would be data from an indeterminate location which includes no information on analytical methodology or QA/QC. In some cases if the missing information were made available, a determination of the suitable uses of the data could be made.

2. Limited-use data. Such data may include adequate sample collection information, following well-documented EPA procedures.

3. Useable Data. This would include data collected and analyzed using CLP methods and documentation. Some non-CLP data meeting analytical Level III DQOs may also be included in this category.

5.2 Nature and Extent of Contamination

It is necessary to have a knowledge of the nature and extent of the constituents of potential concern (COPCs) in exposure media (surface water, groundwater, sediments, soil, and air) and biota. The media and biota serve as potential exposure routes to human receptors and the environment. An understanding of transport and exposure media is required.

5.2.1 Baseline Conditions

In this initial RI, "baseline conditions" refers to the current conditions at the BRMTS mines, as well as on- and off-site areas not considered part of past operations. In this context, background levels of COPCs are important under CERCLA guidance for determination of disposal and remedial alternatives.

5.2.2 Sampling Locations

Locations must be selected to focus on both on- and off-site areas of potential concern. Both systematic and directed (i.e., known areas of high COPC concentration) sample locations can be studied. The locations and numbers of samples must represent acceptable site coverage and provide enough information to allow screening-level statistical analysis. CERCLA guidelines require the documentation of statistics used in either study planning or analysis.

5.3 Summary of Data Quality for CERCLA Applications

In this section, a rigorous data quality review of available site data for CERCLA applications is presented. Based on this review some data is characterized as unusable or of limited use because necessary information on analytical methodology or QA/QC was not available in the reports evaluated. In other cases, if the missing information were made available, a determination of the suitable use of the data could be made. It should also be understood that all data used for this project does not necessarily need to meet stringent DQOs. Preliminary decisions, which may be confirmed by future studies, are sometimes made using data that does not meet DQOs.

Control of Mine Tailing Discharges to Big River, January 1980, J. T. Novak and G. B. Hasselwander, University of Missouri-Rolla

This study presents data on the potential metal leachate from tailings samples tested for leaching by water, EDTA, or nitric acid (Table 5-2). The study was performed by the Department of Civil Engineering, University of Missouri-Rolla for the Missouri Department of Natural Resources (MDNR).

TABLE 5-2
DATA QUALITY, "CONTROL OF MINE TAILING DISCHARGES..."

Site	Media/Analyses	Data Analytical Level	Data Useability
Desloge	Tailings/Potential Metal Leachates	II[a]	Unusable [b]

Notes:
[a] Assumed. Results were presented, but the analytical methodology was not reported.

[b] The source of this data is reported to be the Environmental Research Trace Substance Research Center. The source of the tailings samples is not reported. It is assumed to be Desloge. Sample location, sampling date, sample identity, chain of custody, laboratory report, and QA/QC documentation are not presented.

Preliminary Assessment, Big River Mine Tailings Desloge, St. Francois County, Missouri, May 17, 1988, Ecology and Environment, Inc.

This study primarily presented Desloge tailings analysis data and Big River data on sediment and edible fish flesh (Table 5-3). The work was performed by the Ecology and Environment, Inc. Field Investigation Team for EPA Region VII.

TABLE 5-3
DATA QUALITY, "PRELIMINARY ASSESSMENT..."

Site	Media/Analyses	Data Analytical Level	Data Useability Category
Desloge	Tailing/Potential Metal Leachate	III[a]	Unusable[a]
Big River	Water/Metals Sediment/Metals Fish Flesh/Metals	II[b]	Limited[b]
Leadwood Desloge National Elvins Bonne Terre	Tailings/Metals Tailings/Metals Tailings/Metals Tailings/Metals Tailings/Metals	II[c]	Limited[c]

Notes:

[a] This data was referenced to the study Control of Mine Tailing Discharges to Big River, and was analyzed for that document. As well as other deficiencies, analytical methodology, chain-of-custody, laboratory reports and QA/QC documentation are not presented.

[b] This data was referenced to the study The Dynamics of Metals From Past and Present Mining Activities in the Big and Black River Watershed, Southeastern Missouri, and was analyzed for that document.

[c] This data was referenced to the study A Study on the Possible Use of Chat and Tailings from the Old Lead Belt of Missouri for Agricultural Limestone and was analyzed for that document.

Continued Studies on Vagrant Lead in Fish, Mussels, and Sediments of the Big River of Southeastern Missouri, March 1986, University of Missouri-Rolla

This study presents data on lead concentrations in fish, mollusks and sediments of the Big River collected in 1984 and 1985 (Table 5-4). The work was performed by the University of Missouri-Rolla for the St. Joe Minerals Corporation. The biota and sediment samples were collected in

1984 and 1985. For that reason these results may not be representative of current sediment and biota conditions in the Big River.

TABLE 5-4
DATA QUALITY, "CONTINUED STUDIES..."

Site	Media/Analyses	Data Analytical Level	Data Useability Category
Big River	Biota/Metals	II[a]	Limited[b]
Big River	Sediment/Metals	II[a]	Limited[b]

Notes:
[a] The chain of custody procedures, biota laboratory reports, and complete QA/QC documentation are not provided.

[b] Sampling dates, sampling techniques, and sample numbering was documented, as were sediment laboratory reports, and some QC documentation. Sediment samples were collected and stored in plastic bags which may affect the validity of the samples.

A Study on the Possible Use of Chat and Tailings from the Old Lead Belt of Missouri for Agricultural Limestone, December 1983, B. G. Wixson et al., University of Missouri-Rolla

This study presents data on metal concentrations in the tailings for Leadwood, Desloge, National, Elvins, and Bonne Terre sites (Table 5-5). For the Leadwood tailings pile, samples were collected and analyzed for depths ranging from 3 to 24 feet. This work was performed by the University of Missouri-Rolla for the MDNR.

TABLE 5-5
DATA QUALITY, "A STUDY ON THE POSSIBLE USE..."

Site	Media/Analyses	Data Analytical Level	Date Useability Category
Leadwood	Tailings[a]/Metal	II[b]	Limited[c]
Desloge	Tailings[a]/Metal	II[b]	Limited[c]
National	Tailings[a]/Metal	II[b]	Limited[c]
Elvins	Tailings[a]/Metal	II[b]	Limited[c]
Bonne Terre	Tailings[a]/Metal	II[b]	Limited[c]

Notes:
[a] The samples were collected predominantly near the surface and were reported to represent unweathered portions (20cm depth) of the tailings pile.

[b] The sampling dates, chain of custody procedures, laboratory analysis reports, and laboratory QA/QC documentation was not provided. Samples collected at a depth of 3 to 24 feet were collected courtesy of U.S. Dept. of the Interior Bureau of Mines. The technique employed to obtain uncontaminated samples and sample documentation procedures was not presented in this report.

[c] The sample collection methods, laboratory analysis methods, and QA/QC procedures (16% of study samples were analyzed by the Environmental Trace Substances Research Center, sample duplicates and spiked samples) are described.

The Dynamics of Metals from Past and Present Mining Activities in the Big and Black River Watershed, Southeastern Missouri, September 30, 1982, C. S. Schmitt and S. E. Finger, U.S. Fish and Wildlife Service

This study presents data on metal concentrations in Big River water, sediments, and edible fish flesh (Table 5-6). The work was performed by the U.S. Fish and Wildlife Service for the U.S. Army Corps of Engineers.

TABLE 5-6
DATA QUALITY, "THE DYNAMICS OF METALS..."

Site	Media/Analyses	Data Analytical Level	Date Useability Category
Big River	Water/Metals	II[a]	Limited[b]
Big River	Sediments/Metals	II[a]	Limited[b]
Big River	Fish Flesh/Metals	II[a]	Limited[b]

Notes:
[a] The sampling dates, sample identification system, chain at custody procedure, laboratory analysis reports, and laboratory QA/QC documentation are not presented.

[b] The sample collection methods, laboratory analysis methods and QA/QC procedures (tissue matrix controls, 10% blank samples, 20% blind replicates, and spiked samples) are described. Sample collection dates apparently span 1978 to 1981 and therefore may not be representative of current Big River water, sediment and fish flesh conditions.

Further Characterization and Use of Tailings and Chat from Missouri's Old Lead Belt as Agricultural Lime, 1984, B. G. Wixson et al., University of Missouri-Rolla, and the College of Wales, Aberystwyth, Wales, UK

This publication, which for the most part summarizes data on metal concentrations in tailings, was presented in A Study on the Possible Use of Chat and Tailings from the Old Lead Belt of Missouri for Agricultural Limestone. It was prepared by the University of Missouri, Rolla as a publication for the open scientific literature.

Site Assessment, Big River Mine Tailings Site, Desloge, Missouri, December 20, 1991, Ecology and Environment, Inc.

The majority of the data in this study are total metal and dissolved metal concentrations for water samples from two monitoring wells located on the perimeter of the on-site landfill of the Desloge site and from 44 private wells within a one mile radius (Table 5-7). The study was performed by the Ecology and Environment, Inc. Technical Assistance Team for the EPA Emergency Planning and Response Branch, Region VII.

TABLE 5-7
DATA QUALITY, "SITE ASSESSMENT..." (1991)

Site	Media/Analyses	Data Analytical Level	Date Useability Category
Desloge and 1 Mile Radius	Water/Metals	III[a]	Useable (EPA Laboratory)

Note:
[a] The analysis was performed by the EPA laboratory, in Kansas City, Kansas. The sample chain of custody forms are not presented as part of the report.

HRS Documentation Record, Big River Mine Tailings (St. Joe Minerals Corp., Desloge, Missouri), August 30, 1991, EPA Region VII, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Site Assessment Branch, Washington, D.C.

This document comprises the EPA Hazardous Ranking System (HRS) Documentation Record which was used by EPA Region VII to propose the addition of the Desloge Big River Mine Tailings/St. Joe Minerals Corp. site to the NPL. This package includes a signature page which certifies that the package underwent and passed an EPA quality assurance for proposal to the NPL. The package reviewed did not contain a copy of each of the 40 references cited in the HRS report. The inclusion of all references for an HRS report is standard operating procedure in other EPA regions (e.g., Region VI). Therefore, a Data Analytical Level and Data Useability evaluation will be made on the individual reports as they are encountered.

Bioavailability and Toxicity of Metals Leached from Lead Mine Tailings to Aquatic Invertebrates, 1987, J. M. Besser and C. F. Rabein, University of Missouri, Columbia

This report examines how cover treatment materials added to stabilize tailings deposits in test plots might influence the mobilization mine tailings leachate (Table 5-8). Metal bioaccumulation and toxic effects in invertebrates exposed to leachate were studied. Heavy metal analysis in leachate and biota were performed by atomic absorption (AA). Tailings used were collected from a lead mine tailings pile near Desloge.

TABLE 5-8
DATA QUALITY, BIOAVAILABILITY AND TOXICITY..."

SITE	MEDIA/ANALYSES	DATA ANALYTICAL LEVEL	DATE USEABILITY CATEGORY
Test Plot	Environmental Media/Metals	II[a]	Limited[a]
Test Plot	Biota/Metals	II[a]	Limited[a]

Notes:
[a] Sample identification procedures are not documented.

[b] Laboratory analysis reports and QA/QC documentation are not presented.

Preliminary Public Health Assessment for Big River Mine Tailings/St. Joe Minerals, Desloge, Missouri, January 12, 1994, Missouri Department of Health and the Agency for Toxic Substances and Disease Registry

This document does not present new data. Its purpose is to summarize data currently available about the site. Results of the 1982 U.S. Fish and Wild Life Service study for Big River water sediment and biota metal concentrations are presented. This data may not represent current water and sediment/lead concentrations. Compared to the surface water and sediment lead concentrations reported in the EPA LSI report of 1991, the surface water total and dissolved lead and sediment lead values appear to be decreasing over time. Biota lead and cadmium levels are also reported from a 1982 study. Likewise, biota levels of lead may have decreased since the 1982 study.

Site Assessment, Big River Mine Tailings, Desloge, Missouri, Addendum Report, February 17, 1993, Ecology and Environment, Inc.

This addendum report presents the results of metal analysis conducted on 35 water samples collected from residential drinking wells near the Desloge site and a spring near the site (Table 5-9). The samples were collected August 19-20, 1992. This work was performed by the Ecology and Environment, Inc. Technical Assistance Team for EPA Region VII, Emergency Planning and Response Branch. The sample analysis were performed by the Region VII EPA Laboratory.

TABLE 5-9
DATA QUALITY, "SITE ASSESSMENT..." (1993)

Site	Media/Analyses	Data Analytical Level	Date Useability Category
Desloge and Vicinity	Water/Metals	III[a]	Useable (US EPA Laboratory)

Note:
[a] The analysis was performed by an US EPA Laboratory, Kansas City, Kansas. Chain-of-custody forms were not presented as part of the report. The report states that the total field method accuracy cannot be determined for the water samples because field spiking samples were not performed.

Site Assessment, Big River Mine Tailings, Desloge, Missouri, December 14, 1992, Ecology and Environment, Inc.

This report summarizes the results of field work conducted August 19-25, 1992, on and in the vicinity of the Desloge site (Table 5-10). This work was performed by the Ecology and Environment, Inc. Technical Assistance Team for EPA Region VII, Emergency Planning and Response Branch. As part of this study soil, tailings, and ground water samples were collected and analyzed for metals.

TABLE 5-10
DATA QUALITY, "SITE ASSESSMENT..." (1992)

Site	Media/Annual	Data Analytical Level	Data Useability
Desloge and Vicinity	Tailings and Soil/Metals (XRF)	II[a]	Limited[b]
Desloge and Vicinity	Tailings and Soil/Metals (by analysis)	III[c]	Useable
Desloge and Vicinity	Groundwater/Metals	III[d]	Useable[d]

Notes:
[a] The Quality Assurance Sampling Plan defined the XRF as a level II analytical method.

[b] *The correlation coefficient* between XRF and laboratory data for tailings and soils were 0.44 and 0.51 respectively. This means the XRF data are of limited useability.

[c] The laboratory analysis was performed by an US EPA Region VII laboratory. However, the laboratory report approval letter is not signed by the EPA project leader. The report contains field sheets and Chain of Custody Forms for the samples collected. Samples were collected August 19-25, 1992. All samples were received by the laboratory on August 26, 1992. The field sheets are not all properly signed and dated. Documentation is not provided for the storage of the samples from time of collection to delivery to the laboratory. The condition of the samples at the time of receipt at the laboratory is not documented.

[d] The laboratory reports for these data were documented in Study 120.2.62.R Site Assessment: Big River Mine Tailings, Desloge, Missouri, Addendum Report February 17, 1993.

Listing Site Inspection, Final Report, Big River Mine Tailings, Volumes I and II, October 30, 1991, Ecology and Environment, Inc.

This Listing Site Inspection report summarizes the results of field work conducted August 21-29, 1990, on and near the Desloge site (Table 5-11). This work was performed by the Ecology and Environment, Inc. Field Investigation Team for EPA Region VII. As part of this study soil, tailings, sediment, surface water, groundwater, and air samples were collected and analyzed for heavy metals.

TABLE 5-11
DATA QUALITY, "LISTING SITE INSPECTION..."

Site	Media/Analyses	Data Analytical Level	Data Useability
Desloge and Vicinity	Soil/Metals	III[a]	Useable
Desloge and Vicinity	Tailings/Metals	III[a]	Useable
Big River and Tributaries	Sediment/Metals	III[a]	Useable
Big River and Tributaries	Water/Metals	III[a]	Useable
Desloge and Vicinity	Groundwater/Metals	III[a]	Useable
Desloge and Vicinity	Air/Metals	III[a]	Useable

Note:
[a] The laboratory analysis was performed by an USEPA contractor in Kansas City, Kansas for Region VII. A data transmittal cover letter from the Chief, Laboratory Branch, USEPA Region VII states that the data have met all quality assurance requirements unless indicated otherwise in a data package.

Volume II contains field sheets and Chain-of-Custody sheets for the samples collected. Samples were collected July 21-29, 1990, and reported stored at 4°C. All samples were reported received by the EPA laboratory on July 30, 1990. Documentation is not provided to substantiate the storage of the samples at 4°C from the time of collection to delivery at the laboratory. The condition of the samples at time of receipt by the laboratory is not documented. Field data sheets contain numerous data strike outs and corrections which are not signed and dated. None of the field data sheets have signatures and signature dates by the field personnel who collected the samples.

Elemental Composition of Selected Native Plants and Associated Soils from Major Vegetation-Type Areas in Missouri, 1976, J. A. Erdman et al., U.S. Geological Survey

This report presents data on the elemental composition of native plants and associated soils from six major vegetation-type areas sampled throughout Missouri (Table 5-12). Stem samples from woody (tree and shrub) plants were sampled. Soil samples were exclusively collected from the zone of accumulation constituting the B horizon. The B horizon depth varied from less than 30 centimeters to about 80 centimeters depending on soil type. Plant samples were cut into segments and sealed in quart-sized freezer cartons and shipped to the Denver laboratories. Approximately 300-400 grams of soil samples were put into waterproof paper envelopes and shipped to the laboratories. The types of laboratory analysis methods employed were listed. Samples were randomized prior to laboratory submittal, and selected samples were divided into two portions to provide duplicate samples for analysis. This United States Geological Survey (USGS) geochemical survey (Professional Paper 954-C) was prepared by J. A. Erdman, H. T. Shacklette, and J. R. Keith.

TABLE 5-12
DATA QUALITY, "ELEMENTAL COMPOSITION..."

Site	Media/Analyses	Data Analytical Level	Date Useability Category
Missouri	Plant/Elemental	II[a]	Limited[b]
Missouri	Soil/Elemental	II[a]	Limited[b]

Notes:
[a] The analytical methods used in this study were listed in the report.

[b] Sample storage and transportation, chain of custody procedures, laboratory analysis reports, and laboratory QA/QC documentation were not presented in the summary report.

Hydrochemical and Sediment Data for the Old Lead Belt, Southeastern Missouri, 1988-1989, B. J. Smith et al., U.S. Geological Survey

This report presents data on surface water discharge, water quality samples collected at 12 sites quarterly from 1988 to 1989, water quality and suspended-sediment samples collected during flood sampling at two sites, and water quality and discharge measurements at two seepage sites (Table 5-13). The 12 water quality study sites included 4 on the Big River, 2 on the Flat River, 4 seeps from tailings, an abandoned exploration drill hole, and a site at the base of a tailings pile. Field measurements were made of specific conductance, pH, water temperature, and alkalinity. Water quality samples were analyzed for inorganic constituents using methods described by Fishman and Friedman (1988) at the USGS National Water-Quality Laboratory in Arvada, Colorado. Dried suspended sediment was analyzed for total-element content by inductively coupled plasma using the USGS Geochemistry Laboratories in Denver, Colorado. This USGS Open-File (91-211) was prepared by B. J. Smith and J. G. Schumacher in cooperation with the MDNR, Land Reclamation Commission.

TABLE 5-13
DATA QUALITY, "HYDROCHEMICAL AND SEDIMENT..."

Site	Media/Analyses	Data Analytical Level	Date Useability Category
Big River/ Flat River	Surface Water/Daily Discharge Rate	I[a]	Limited[b]
Big River/ Flat River/ Tailings	Surface Water/Inorganic Constituents, Physical Parameters	I,II[a]	Limited[b]
Big River/ Flat River/ Flood Sampling	Surface Water/Water Quality, Suspended Sediment	I,II[a]	Limited[b]
Big River/ Flat River Seepage Study	Seepage/Water Quality	I,II[a]	Limited[b]

Notes:
[a] The analyses ranged from field measurements to ICP AA.

[b] Sampling procedures, sample storage and transportation, chain of custody procedures, laboratory analysis reports, and laboratory QA/QC documentation were not provided in the summary report reviewed.

Lead Contamination of Sycamore and Soil from Lead Mining and Smelting Operations in Eastern Missouri, March 1980, K. T. Palmer et al., Ministry of the Environment, Toronto, Ontario

This report presents lead concentrations in washed plant tissues from Sycamore trees and soil in eastern Missouri at six locations, including the Desloge mine (Table 5-14). Lead determinations were performed using AA spectrophotometry. Soil sample lead assays were reported performed by the staff of the laboratory of the St. Joe Minerals Corporation in Herculaneum, Missouri. The authors of the report were K. T. Palmer, Head, Phytotoxicology Section, Air Resources Branch, Ministry of the Environment, Toronto, Ontario, and C. L. Kucera, Professor, Division of Biological Sciences, University of Missouri, Columbia, Missouri. This report was published in the Journal of Environmental Quality, Volume 9, January - March 1980, and appears to be based on field studies ca. 1969-1972.

TABLE 5-14
DATA QUALITY, "LEAD CONTAMINATION..."

Site	Media/Analysis	Data Analytical Level	Data Useability Category
Missouri	Plant/Lead	II[a]	Limited[c]
Missouri	Soil/Lead	II[a,b]	Limited[c]

Notes:
[a] The analytical assay technique was simply described as atomic absorption spectrophotometry.

[b] Soil samples were simply described as a composite of three randomly selected 15.2 cm cores, collected at each site. The distance of the soil samples from the Sycamore tree is not reported. Whether the soil samples were surface or subsurface samples is not reported.

[c] Sample identification, storage, transport, chain of custody procedures, laboratory analysis reports, and laboratory QA/QC documentation were not presented in this summary report.

Toxic Heavy Metals in Vegetables and Forage Grasses in Missouri's Lead Belt, 1973, D. D. Hemphill et al., University of Missouri, Columbia

This report presents lead and cadmium concentrations in vegetables and forage grasses grown in the Old Lead Belt and control counties (Table 5-15). Metal analysis was simply reported as AA spectrophotometry. Vegetables were washed prior to analysis but forage grasses were not. This report is by D. D. Hemphill, C. V. Marienfrld, R. S. Reddy, W. D. Heidlage, and J. O. Pierce of the Environmental Health Surveillance Center, University of Missouri, Columbia, Missouri, and was published in the Journal of the AOAC, Volume 56.

TABLE 5-15
DATA QUALITY, "METALS..."

Site	Media/Analysis	Data Analytical Level	Data Useability Category
Missouri	Foliage/Metals	II	Limited[a]

Note:
[a] Sample identification, storage, transport, chain of custody procedures, laboratory analysis reports, and laboratory QA/QC documentation were not presented in this summary report.

An Evaluation of the Acute Toxicity of Lead, Zinc, and Cadmium in Missouri Ozark Groundwater, N. L. Gale et al., University of Missouri-Rolla

The report presents the results of a bench top laboratory study of the acute toxicity of added lead, zinc, and cadmium in nonchlorinated well water or dechlorinated tap water to fathead minnows and daphnids, using EPA procedures (Table 5-16). At the end of the 48-hour daphnid test, an aliquot of each test vessel was collected and analyzed for metals by AA spectrophotometry and ICP-emission spectroscopy at the Environmental Trace Substances Research Center, Columbia, Missouri. The report was by N. L. Gale (University of Missouri, Rolla), B. G. Wixson, and M. Erten. The study was supported in part by the MDNR.

TABLE 5-16
DATA QUALITY, "AN EVALUATION..."

Analysis	Data Analytical Level	Data Useability Category
Acute Metal Toxicity in Water	II	Limited[a]

Note:
[a] Metal analysis sample identification, storage, transport, chain of custody procedures, and laboratory QA/QC documentation were not presented in this summary report. Good Laboratory Practices documentation for these laboratory animal studies is not provided.

Assessing the Validity of Lead Bioavailability Estimates from Animal Studies, March 1993, R. A. Schoof et al., P.T.I. Environmental Services

This report examines published lead bioavailability animal studies. The purpose is to determine how factors, which affect lead bioavilability such as stomach acidity, food transit times, and anatomical structure, affect the relevance of animal results in predicting lead bioavailability in children. This is a reprint of a poster presentation given at the Annual Meeting of the Society of Toxicology (Abstract No. 478, March 1993) by R. A. Schoof, M. J. Steele, C. P. Boyce and C. G. Evans of P.T.I. Environmental Services. This document reviews data from other sources and presents no new data.

Suggested Removal Action Alternative for Consideration in Controlling Wind Erosion and Bank Stabilization, Big River Mine Tailings Site, Desloge, Missouri, March 1993, St. Joe Minerals Corporation

This report proposes remedial actions for Desloge, including grading drainage basins, surface stabilizers, revegetation, and other drainage improvements. The report does not present any new data which needs to be evaluated. It was prepared by the St. Joe Minerals Corporation.

Draft Engineering Evaluation/Cost Analysis for the Big River Mine Tailings Site, Desloge Missouri (A Non-Time-Critical Removal Action for Dust Control, Bank Stabilization, and Storm Water Runoff Control), December 1993, U.S. EPA Region VII

This document was issued by EPA Region VII, Kansas City, Kansas. The purpose of this engineering evaluation/cost analysis is to screen and evaluate removal action alternatives for controlling wind the erosion and storm water runoff and erosional stability of the banks and slopes of the Desloge site. The document does not present any new data that needs to be evaluated.

Water Quality Surveys of the Southeast Ozark Mining Area, Missouri Department of Conservation

1965-1971, August 1974, F. M. Ryck, Jr.
1981, May 1983, L. Trial
1974, May 1975, F. M. Ryck, Jr.
1975, May 1977, F. M. Ryck, Jr.
August 1981, L. Trial and E. F. Robinson-Wilson
1972-1973, March 1974, F. M. Ryck, Jr.

This series of reports on the water quality of the Southeast Ozark Mining Area was based on studies of bottom-dwelling invertebrates (Table 5-17). The species diversity index and number of taxa of pollution sensitive mayflies and stoneflies of unpolluted streams were compared to those of polluted streams. Additionally, since these studies covered the period 1965 to 1981, the condition of individual streams over time was assessed. The methods used for the invertebrate species survey are described in the report issued in August 1974. The Flat River Creek in the Big River drainage is consistently included in those surveys.

TABLE 5-17
DATA QUALITY, "WATER QUALITY SURVEY..."

Site	Media/Analysis	Data Analytical Level	Data Useability Category
Big River/Flat River Creek	Sediment/Species Diversity Number of Taxa	I[a]	Limited[b]

Notes:
[a] A detailed description of laboratory sample information/data tracking and recording is not given in these summary reports.

[b] Sample labeling information and QA/QC procedures are not described.

Big River, Big Problem, J. R. Whitley, Unknown Publication, No Date

This narrative article about the Big River mine tailings problems presents no data that needs to be evaluated.

Missouri Stream Pollution Survey, January 1974, F. M. Ryck, Jr., Missouri Department of Conservation

This report covers stream conditions spanning November 1967 to September 1971, and presents no data that needs to be evaluated.

Various Studies, University of Missouri-Rolla

Investigation of Clear Water Lake as a Potential Site for Heavy Metals from Lead Mining in Southeast Missouri, ca. late 1970s, N. L. Gale et al., University of Missouri-Rolla

Chemistry and Plant Ecology of Zinc-Rich Wastes Dominated by Blue-Green Algae, 1981, B. A. Whitton et al., University of Missouri-Rolla

Influence of Tailings From the Old Lead Belt of Missouri on Sediments of the Big River, 1982, B. G. Wixon et al., University of Missouri-Rolla

Lead Concentration in Edible Fish Filets Collected from Missouri's Old Lead Belt, 1982, N.L. Gale et al.

Lead in Fish from Streams in the Old and New Belt of Missouri, ca. 1983, N. L. Gale and B. G. Wixson

Fish from Missouri's Lead Belt: To Eat or Not to Eat, 1985, N. L. Gale and B. G. Wixson

Continued Evaluation of Lead in Fish and Mussels in the Big River of Southeastern Missouri, 1985, N. L. Gale and B. G. Wixson

Lead Studies on Fish, Mussels, and Sediments in Big River of Southeast Missouri, 1985, N. L. Gale and B. G. Wixson

This series of publications, concerned with the lead (and other heavy metal) levels in rivers and streams, sediments, and aquatic biota from the Old Lead Belt, is by the same group of authors from the University of Missouri-Rolla (Table 5-18). These publications span the late 1970s to 1985. The first and second papers deal with Clearwater Lake and the Elvins Tailings Pile, respectively. The remainder focus on the Big River and Flat River Creek. Environmental samples collected for these studies include: surface water, sediments, tailings, algae, fish, and mussels. The samples were analyzed for lead, or for a series of metals which usually included lead, cadmium and zinc. Sample collection methods are briefly described (plastic bags were frequently used to store samples). Analysis descriptions are terse. The first two publications simply state "A.A." or "Atomic Absorption." The remainder of the publications state AA analysis by the Environmental Trace Substances Research Center, Columbia, Missouri. For QA/QC, one publication simply states that standard additions were made to correct for matrix effects.

TABLE 5-18
DATA QUALITY, "VARIOUS STUDIES"

Sites	Media/Analysis	Data Analytical Level	Data Useability Category
Big River/Flat River Creek/Clearwater Lake/Elvins Tailings Pile	Water, Sediment, Biota/Metal Analysis	II[a]	Limited[b]

Notes:
[a] Metal analysis methodology, sample identification, storage, transport, and chain of custody procedures are not presented.

[b] Laboratory analysis reports and QA/QC documentation are not presented.

Accumulation of Lead in Fish From Missouri Streams Impacted by Lead Mining, 1985, J. M. Czarnezki, Missouri Department of Conservation, Columbia

Use of the Pocketbook Mussel, Lampsilis ventricosa, for Monitoring Heavy Metal Pollution in an Ozark Stream, J. M. Czarnezki, Missouri Department of Conservation, Columbia

The first report presents data on fish lead concentrations in Missouri streams, including the Big River, while the second report presents data on mussel lead and cadmium levels in caged pocketbook mussels planted at various locations in the Big River (Table 5-19). The first report states that fish tissue samples were analyzed by a private laboratory. The second report states that the private laboratory used graphite furnace AA, and that the quality control program consisted of duplicate analysis on 10 percent of samples, that 10 percent of samples were spiked, and that NBS reference samples were analyzed.

TABLE 5-19
DATA QUALITY, "ACCUMULATION OF LEAD..."

Site	Media/Analysis	Data Analytical Level	Data Useability Category
Big River	Biota/Pb, Cd	II[a]	Limited[b]

Notes:
[a] Metal analysis methodology, sample identification, storage, transport, and chain of custody procedures are not documented.

[b] Laboratory analysis reports and QA/QC documentation are not presented.

Bioavailability of Pb and Zn from Mine Tailings as Indicated by Erythrocyte δ-Aminolevulinic Acid Dehydratase (ALA-D) Activity in Suckers (Pices:Catostomidae), 1984, C. J. Schmitt et al., U. S. Fish and Wildlife Service, Columbia, Missouri.

Lead in Missouri Streams: Monitoring Pollution from Mining with An Assay for Erythrocyte δ-Aminolevulinic Acid Dehydratase (ALA-D) in Fish Blood, C. J. Schmitt et al., U.S. Fish and Wildlife Service, Columbia, Missouri

These two reports present data on fish blood δ-Aminolevulinic Acid Dehydratase (ALA-D) activity and blood-lead levels (plus cadmium and zinc, in the second report) in fish from the Big River (Table 5-20). The ALA-D activity methodology is described. The metal analyses were performed by AA by the Environmental Trace Substance Research Center (University of Missouri). The second paper states quality control for elemental concentrations by ICP and AA included evaluation of accuracy through analysis of reference materials, procedural blanks, and spiked samples, and evaluation of precision through duplicate sample analysis.

TABLE 5-20
DATA QUALITY, "BIOAVAILABILITY OF Pb AND Zn..."

Site	Media Analysis	Data Analysis Level	Data Useability Category
Big River	Blood/ALA-D	II[a]	Limited[b]
Big River	Blood/Pb,Cd,Zn	II[a]	Limited[b]

Notes:
[a] Sample identification, transport, and chain of custody procedures are not documented.

[b] Laboratory analysis reports and QA/QC documentation are not presented.

Use of Sequential Extraction to Evaluate the Heavy Metals in Mining Wastes, 1990, T. E. Clevenger, University of Missouri-Columbia

Lead-zinc mine tailings from sites near the town of Desloge were chemically characterized using total chemical analysis and sequential extraction (Table 5-21). Analyses for lead, zinc, copper, and cadmium were performed using AA by the Environmental Trace Substance Research Center.

TABLE 5-21
DATA QUALITY, "USE OF SEQUENTIAL EXTRACTION..."

Sites	Media/Analysis	Data Analytical Level	Data Useability Category
Near Desloge, Missouri	Tailings, Extraction Samples/Pb, Zn, Cu, Cd	II[a]	Limited[b]

Notes:
[a] Sample identification and chain of custody procedures are not documented.

[b] Laboratory analysis reports and QA/QC documentation are not presented.

Uptake of Lead from Aquatic Sediment by Submersed Macrophytes and Crayfish, 1983, M. F. Knowlton et al., University of Missouri, Columbia and U.S. Department of the Interior, Fish and Wildlife Service, Columbia-Missouri

This document presents the uptake of lead by submersed aquatic macrophytes and crayfish exposed to artificially contaminated pond sediment under laboratory conditions (Table 5-22). Lead was determined by AA. Natural Bureau of Standards tissue standards were analyzed as part of quality control.

TABLE 5-22
DATA QUALITY, "UPTAKE OF LEAD..."

Site	Media/Analysis	Data Analytical Level	Data Useability Category
Laboratory Study	Biota/Pb	II[a]	Limited[b]

Notes:
[a] Sample identification procedures are not documented. This study predates Good Laboratory Practices guidelines for animal studies.

[b] Laboratory analysis reports and QA/QC documentation are not presented.

Biochemical Changes in Longear Sunfish, Lepomis megalotis, Associated with Lead, Cadmium, and Zinc from Mine Tailings, F. J. Dwyer et al., U.S. Fish and Wildlife Service, Columbia, Missouri

Longear sunfish were collected from the Big River (Table 5-23). Blood samples were analyzed for δ-Aminolevulinic Acid Dehydratase (ALA-D) activity and lead concentrations. Other tissues were analyzed for lead, cadmium, and zinc concentrations. The ALA-D activity methodology is described. Metal analysis were performed by AA. The quality control included the use of National Bureau of Standards tissues. During analysis, blanks, blind replicates, and spiked samples were analyzed.

TABLE 5-23
DATA QUALITY, "BIOCHEMICAL CHANGES..."

Site	Media/Analysis	Data Analytical Level	Date Useability Category
Big River	Blood/ALA-D	II[1]	Limited [b]
Big River	Tissues/Pb,Cd,Zn	II[a]	Limited[b]

Notes:
[a] Sample identification, transport, and chain of custody procedures are not documented.

[b] Laboratory analysis reports and QA/QC documentation are not presented.

5.4 Data Gaps

Data needs have been summarized by site (Section 5.4.1) and by media (Section 5.4.2).

5.4.1 Data Needs Summarized by Site

The data available to characterize the nature and extent of environmental impacts at the sites in the Old Lead Belt is of variable quality. The most complete and detailed information is available for the Desloge site. Tailings characterization data is available for the Desloge, National, Leadwood, Elvins, and Bonne Terre sites. Very little data is available for the Hayden Creek, Doe Run, and Federal sites. Background concentration levels for metals are only available for the Desloge site. Sediment, surface water, and edible fish flesh data is available for several sites along the Big River. The purpose of this section is to briefly identify data gaps in site information and recommend data sets necessary to characterize the nature and extent of BRMTS contamination.

Desloge

The Desloge site has been the subject of extensive characterization studies of the tailings, plus air quality. For the human health risk assessment, data is needed to characterize the lead, cadmium, and zinc content of the top six inches of the surface soil and to characterize the lead, cadmium, and zinc content of respirable fugitive dust emissions. The air quality data for Desloge will be used as a representative estimate of air quality of the other sites.

Additional site characterization data will become available after the joint ATSDR/MDOH blood lead and environmental lead study is conducted in the Old Lead Belt. The environmental sampling and laboratory analyses are expected to begin this summer and finish by late 1995.

National, Leadwood, Elvins, Bonne Terre, and Federal Sites

For the National/Flat River, Leadwood, Elvins/River Mines, Bonne Terre, and Federal sites, additional surface characterization of the top six inches of the waste tailings is needed for the human health risk assessment exposure scenarios. Human population data is also required.

Doe Run and Hayden Creek Sites

Very little data is available for the Doe Run and Hayden Creek sites. Waste pile footprint and characterization data and human population data are needed.

Big River Sediments

The reported release of about 50,000 cubic yards of waste material into the Big River during a storm in 1977 was the reason for the focussed interest on the metal content of sediment, water, and fish flesh along the Big River. Studies reported in 1982 and 1992 provide the bulk of the available characterization data for the Big River sediments.

The characterization and stabilization activities at the sites will be conducted with the short-term goal of reducing the potential for future releases of contaminated material into the Big River from the collective sites. The sites are primarily individual sources of the same materials. After this goal is attained, it would be advisable to assess the need for current data on the metal content of Big River surface water, sediment, and fish and other aquatic biota, for estimating environmental risks and for risk management decisions by environmental media.

5.4.2 Data Needs Summarized by Media

The following section provides a summary of data needs by environmental media.

Air

- Air monitoring data at the Federal site, which may represent worst or near worst case situation, indicated no problem with either TSP or lead. This is consistent with BS/T and Jasper County sites.
- Any potential problems would be addressed by planned stabilization efforts.
- Therefore, no real data need for decision on air quality.
- May collect inhalable particulate data at the fenceline as input to the baseline human health risk assessment.

Surface Water

- Available water quality data indicate that streams met or typically met ALCs.
- Any exceedances or problems with surface water quality have been related to sediment, which will be addressed as part of on site stabilization effort.
- Only potential data need is to confirm the sediment/water quality relationship

Groundwater/Drinking Water

- A fair amount of data exists for groundwater quality from water districts and other sources.
- Any existing problem concerning groundwater can not be remediated.
- Therefore, a key data need will be to define both areas served by existing water districts, and areas not served (i.e., private wells) and to document water quality of each. Data on areas served by water districts and the water quality of the district should be available.
    - Are there areas not covered by water districts.
    - How many residents are in this group.
    - Will these or a subset of these be sampled as part of blood-lead study.

Tailings

- Have data to generally characterize tailings.
- Key data needs would be the physical (detailed maps, etc.) that engineers would need to design stabilization measures and that revegetation experts need to evaluate reclamation (revegetation).
- Also need to identify that no homes built on mine wastes.

Soils

- Need to define how metals have migrated from tailings.
- Sampling will be complicated by the proximity of residential areas (with lead-based paint) to most tailings.

Data needs are summarized in Table 5-24. Much data is available on soil, air quality, wastes, ecological receptors, and tailings. Areas of specific data needs are identified in the table. Specific data needs will be addressed by the proposed sampling conducted during this summer's field studies.

TABLE 5-24
IDENTIFIED DATA GAPS[a]

Site Information/ Data Set	Site									
	Desloge		National/ Flat River	Leadwood	Elvins/ River Mines	Bonne Terre	Federal	Doe Run	Hayden Creek	Big River
	Chat Pile	Landfill								
Site History	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Data Gap	Complete	Complete
Site Plot Plan	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Data Gap	Complete	Complete
Topographic Map	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete
Waste Data[b]	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Data Gap	Data Gap	Not Applicable
Ecological Receptors[b]	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap
Human Receptors	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete
Soil[b]	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap
Sediment	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete
Groundwater	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap
Surface Water (Big River)	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete
Surface Water (Wetlands)	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap
Air Quality[b]	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete
Human Health Risk Assessment Data Set:										
Blood Lead	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap
Tailing/Surface[b] Samples	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap
Air[b]	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap
Residential Dust	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap
Drinking Water	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap	Data Gap

Key: Complete = Adequate information available
[a]The Sampling by MDOH and Doe Run in Summer 1995 is anticipated to address all data gaps.
[b]Much data is available on soil, air quality, tailings, and ecological receptors. Specific data needs will be addressed by proposed sampling conducted during field studies this summer.
[c]Wetlands, on-site ponding, on-site tributaries.

5.5 Sampling and Analysis Plans

This Field Sampling Plan (FSP) identifies the samples needed to fill BRMTS data gaps and meet data quality objectives (DQOs). The methods to be used to collect the samples are also presented. The Old Lead Belt is geographically large and complex, with many issues to be resolved before the BRMTS can be considered fully remediated. The scope of this initial RI is to identify and prioritize the sites so that resources can be applied in a cost-effective and timely manner to address the issues pertaining to the public health and the environment.

This section presents the preliminary draft of the FSP. The Health and Safety Plan (Appendix B) and the Quality Assurance Project Plan (Appendix C) are considered part of the FSP.

5.5.1 Summary of Site History

The history of the BRMTS is presented in Section 1.0. Once the FSP is issued as a standalone plan, a brief summary will be presented in this section.

5.5.2 Data Objectives

All data gathered in support of the initial RI must be of sufficient quality and be collected in sufficient frequency to meet the objectives of the study. The first step in the collection of field data is to identify the DQOs for the study. DQOs are qualitative and quantitative statements which clearly identify the data needs and rationale that will guide the collection of field data. For the BRMTS, the following DQOs have been identified:

1. Identify and prioritize sites within St. Francois County for interim remedial actions and non-time critical removal actions to maximize protection of human health and the environment

2. Visually identify sources and pathways of contaminant entry into the surface water pathway and the environment.

3. Quantitate the current emissions of metals into ambient air, attributable to each site.

4. Visually delineate the extent of waste at each of the sites.

5. Characterize the waste on the surface of the waste tailings, facilitating the estimation of risk to potential receptors on the waste sites.

6. For ecological risk screening for terrestrial receptors, the concentration of COPCs in the mouse will be characterized. Using the Leadwood site as a representative site, mice will be collected and analyzed to determine levels of lead, cadmium and zinc. (The field sampling plan for these DQOs is in preparation and will be added to a later version of this document.)

7. Based on a review of available aerial photographs and a site visit by a field biologist a general vegetation and wildlife map including mapping of wetland areas, will be developed for the site. Representative samples of a common wetland species will be collected and analyzed to determine lead, cadmium and zinc concentrations.

5.5.3 Sample location and Numbers

Eight sites have been identified where mining activity has resulted in extensive tailings, and/or tailings impoundments. These eight sites are:

1. Desloge
2. National
3. Leadwood
4. Elvins/Rivermines
5. Bonne Terre
6. Federal
7. Doe Run
8. Hayden Creek

In addition, the Big River has been identified as a "site," although the river is obviously not the location of a tailings. The mine/tailings pile at the Desloge site has been the subject of intense study, and therefore additional sampling efforts are not required at this time. The Big River will not be sampled during this phase of work because it is not considered a source area. Data pertaining to the composition of the mine/tailings for the other sites is erratic. The purpose of sampling the tailings at the sites is to demonstrate that the waste products are essentially the same. This is believed to be the case because the lead ore which was the source of the tailings throughout the county was from the same deposit. The sites which will be subject to sampling during the initial RI are National, Leadwood, Elvins/Rivermines, Bonne Terre, Federal, Doe Run, and Hayden Creek. It is believed that at Doe Run and Hayden Creek, the tailings have been removed, so sampling there will focus on any identifiable footprints from the former tailings. The sites are shown in Figure 3-1 (Section 3.0). Generally, the analytical data for each of the site is incomplete and of indeterminant quantity. Therefore, it is proposed that the following samples be collected at each of the sites:

- Surface samples of the tailings from each site
- Upwind and downwind total particulate and PM_{10} particulate samples from the Desloge site.

In addition to the samples of tailings which will be collected, each site will be inspected for evidence of wash out and release of tailings to surface water. This information is necessary to help prioritize response activities through out the BRMTS.

Surface samples of the tailings will be collected from each of the sites at 10 locations. These locations will be randomly selected by the sampling team. The samples will be used to characterize the potential wind-blown tailings and to calculate exposure for the baseline risk assessment. At each location, a sample of the surface material will be collected at a depth ranging from 0 to 6 inches. The surface area of the sample will be adjusted to ensure sufficient sample is provided to the laboratory for the proposed analyses.

Air samples will be collected from upwind and downwind locations from the Desloge site. The weather forecast for the area will be consulted to determine the wind direction expected for that day. Total particulate and PM_{10} particulate will be collected from each sample point. The exact locations of the air samples will be determined in the field based on the wind speed and direction and power availability at the time of sampling. The Desloge site has been selected because it has been the subject of a previous study relating to the emission of total suspended particulate (TSP) and will allow correlation of PM_{10} with TSP levels of the COPCs.

A previously noted, the data quality levels for each of the sample types are based on consideration of the potential data uses and guidance from current EPA publications on DQOs. Surface material samples and air samples will require Level IV data packages. No additional sampling of the sediments or water in the Big River or groundwater is planned during this initial RI.

5.5.4 Sample Identification and Designation

All samples collected at the sites will be assigned a unique sample identification number to distinguish an individual sample from all other samples. This identification number will be used on all documentation relating to collection, handling, analysis, and reporting of the analytical results of each individual sample. Since a sample is normally analyzed for several different chemical constituents or parameters that require different sample containers and preservation techniques, the same sample identification number will be assigned to each portion of the original sample split among individual sample containers. The method of identification of a sample will depend on the type of measurement or analysis performed.

Sampling at the sites will include tailings and air. Samples will be numbered in consecutive order as they are collected. Duplicate samples will also be numbered consecutively, and will be identified as duplicates only on field data forms. The following sample designation procedure will be used:

loc-xx-#

loc	=	location of sample (site name)
xx	=	type of media sample (TL=tailings, AR=air)
#	=	sample number for sample location

Quality control samples will also be numbered and designated as the following:

Trip Blank-#
Equipment Blank-#

Sample labels provided by the laboratory will be affixed to each individual sample collected. The label on all samples collected during the site investigation will contain the following information:

- Project name and location
- Project number
- Sample location
- Sample identification number
- Date and time of collection
- Name or initials of sampler
- Analyses to be performed

5.5.5 Sampling Equipment and Procedures

Tailings samples from the sites will be collected in accordance with EPA Region VII standard operating procedures. These procedures describe the methods for collecting representative samples which may be used to determine whether concentrations of specific compounds are present above action levels and/or whether they pose a risk to public health and the environment.

Tailings samples will be collected using hand trowels or hand augers depending on the depth of desired sample.

Air sampling will be accomplished by an expert subcontractor under the direct supervision of Fluor Daniel. The subcontractor will be required to submit for review the standard operating procedures for total particulate and PM_{10} sampling prior to initiation of field activities. Fluor Daniel will ensure that all subcontractor activities meet EPA Region VII requirements for air monitoring and testing.

5.5.6 Equipment Decontamination Procedures

All material and equipment that come in contact with potentially contaminated materials will be decontaminated prior to and after each use. Decontamination of equipment will prevent or minimize cross contamination in sampled media and in samples, which is important for preventing the introduction of errors into sampling results and for protecting the health and safety of site personnel. Decontamination will consist of steam cleaning, or a nonphosphate detergent scrub, followed by fresh water and distilled water rinses. After material and equipment are decontaminated, they will be stored on clean plastic sheeting in an uncontaminated area.

Decontamination procedures will be performed in accordance with EPA Region VII standard operating procedures. The following decontamination procedures will be used for sampling material and equipment:

- Soil samplers will be cleaned prior to initial use and between uses. Samplers will either be steam cleaned between uses, or by the following procedure:

  - Nonphosphate detergent wash
  - Tap water rinse
  - Distilled water rinse (2 to 3 times)

- Trowels and hand augers used to collect soil samples will either be steam cleaned between samples, or by the following procedure:

  - Nonphosphate detergent wash
  - Tap water rinse
  - Distilled water rinse (2 to 3 times)

5.5.7 Sample Handling and Analysis Procedures

All samples will be handled according to the procedures contained or referenced in this section. Glass sample containers used precleaned by the laboratory. No preservatives are expected to be required because the samples are tailings which contain high levels of metals. Field logs and sample custody forms will also be maintained and all samples will be labeled as specified in Section 5.5.4. Descriptions of each of these measures are provided below.

The use of proper sample containers is important to ensure the representativeness of the analytical data collected, the sufficiency of sample volumes for analysis, and to reduce the potential for contamination of the sample resulting from the sample container material.

Precleaned sample containers will be supplied by the laboratory in response to a Sampling Supply Request from Field Operations Leader. Sample containers shall remain in storage containers during transport to the sampling location and until the time of actual sample collection to avoid any introduction of contaminants into the sample containers. All samples will be collected in clean, unused containers.

Analytical procedures performed for the BRMTS are restricted to analysis for metals (lead, cadmium, and zinc) using EPA CLP laboratory procedures. Laboratory analytical methods to be used on samples collected as part of this RI are the 200-series of analyses contained in SW 846. Analytes include lead, cadmium, and zinc. Actual detection limits obtained during analysis will be reported for each parameter in each sample. Highly contaminated samples or samples containing interfering substances may result in elevated detection limits. Methods for metals are based on EPA's *Test Methods for Evaluating Solid Wastes* (SW-846, 3rd edition).

All analyses will be performed in accordance with the analytical laboratory's QA/QC plan as well as in accordance with appropriate analytical methods.

5.5.8 Sample Handling and Custody

Sample custody procedures are designed in accordance with EPA and National Enforcement Investigation Council (NEIC) requirements for sample control. To establish the necessary documentation required to trace sample possession from the time of collection to the time of analysis, a Chain-of-Custody form will be completed and will accompany every sample through its transportation to the designated analytical laboratory.

The following information should be completed on the Chain-of-Custody form:

- Project number
- Total samples shipped
- Date samples are relinquished
- Signature of sample collector
- Sample identification
- Date/time samples collected
- Sample type
- Container type
- Sample preservation
- Analyses requested and analytical level
- Signature of person(s) involved in the chain-of-possession

The following chain-of-custody procedures will be implemented to maintain and document sample possession:

1. Samples will be collected as described in this FSP.

2. The Field Operations Leader is personally responsible for the care and custody of the samples collected until they are properly transferred or dispatched to the analytical laboratory.

3. Sample labels will be completed for each sample, using waterproof ink.

4. If a sample label is lost during shipment or a label was never prepared, the following procedure applies: "A written statement is prepared detailing how the sample was collected and transferred to the laboratory. The statement should include all pertinent information such as entries in field log books regarding the sample, whether the sample was in the sample collector's physical possession or in a locked compartment until hand-transported to the laboratory, etc." (NEIC Policy and Procedures, EPA/330/9-78-001-R).

The following procedures will be implemented when transferring custody of samples:

1. Samples are accompanied by a Chain-of-Custody form. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the form. This form documents sample custody transfers from the sampler, often through another person, to the analyst in the laboratory.

2. Samples will be packaged properly for shipment and dispatched to the laboratory for analysis, with a separate custody form accompanying each shipment (i.e., one for the samples retained in the field, one for samples shipped to the off-site laboratory). Shipping containers will be sealed for shipment to the laboratory. The method of shipment, courier name(s), and other pertinent information is entered in the "Special Instructions" section of the custody form.

3. All shipments will be accompanied by the Chain-of-Custody form identifying its contents. The original form will accompany the shipment and a copy will be retained by the Field Operations Leader for inclusion in project records. The completed, original form will be placed inside the shipping container before it is sealed. The courier will not be required to sign the form, since the container is sealed.

4. If sent by mail, the package will be registered with return receipt request. If sent by common courier or air freight, proper documentation must be maintained (i.e., bill of lading).

Samples will be packaged according to the following procedures:

- Custody seal will be wrapped around the end of each container. The custody seal will be signed and dated by the sampler.

- Glass sample containers will be wrapped with plastic insulating material to prevent contact with other sample containers or the inner wall of the cooler.

- Samples will be classified according to the Department of Transportation (DOT) regulations pursuant to Title 49 CFR.

Samples will be packaged in insulated, rigid coolers. Sample containers will be placed in a cooler that contains ice bagged in plastic or Blue Ice, and absorbent packing for liquids or foam packing for solids. The completed Chain-of-Custody form will be placed inside the shipping container, unless otherwise noted. The container will be secured with strapping tape to prevent opening during shipment.

The cooler will be marked as follows:

- Proper shipping name: Hazardous substance, liquid or solid.
- Hazardous class: "This Side Up" or arrows placed on the opposite side of the outer container if liquid is to be shipped.
- Two strips of custody tape are placed on each cooler, with at least one strip at the front and one at the back, located in a manner that would indicate tampering, if any had occurred.

Daily logs will be maintained on-site during field activities by the Field Operations Leader to provide daily records of significant events, observations, and measurements during field operations. Observations or measurements taken in an area where contamination of the field notebooks may occur will be recorded in a separately bound and numbered logbook before being transferred to the project notebook. The original records will be retained, and the delayed entry noted as such. The daily logs will be maintained in a bound field notebook. All entries will be made legibly in indelible ink, signed, and dated. Field notebooks are intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during project investigation. In a legal proceeding, notes, if referred to, are subject to cross examination, and are admissible as evidence. The field notebook entries will be factual, detailed, and objective. Information that will be recorded in the field notebook includes, but is not limited to, the following:

- Date, time, and place of sampling
- Field QC samples, as applicable
- Weather conditions at the time of sampling, including ambient temperature and approximate wind direction and speed
- Data from field analyses (pH, air sampling, etc.)
- Observations about the site and samples (odors, appearance, etc.)
- Information about any activities, extraneous to sampling activities, that may affect the integrity of the samples (e.g., emissions from nearby operations)
- Analyses and required preservation techniques
- Sample cooler temperature readings

Unless restricted by weather conditions, all original data recorded in field notebooks, on sample identification tags, and on Chain-of-Custody forms will be written in waterproof ink. The Chain-of-Custody forms are accountable, serialized documents and are not to be destroyed, even if they are illegible or contain inaccuracies that require a replacement documentation.

If an error is made on an accountable document assigned to one person, that individual will make corrections by crossing out the error with a single line and entering the correct information. The erroneous information should not be obliterated. An error discovered on an accountable document will be corrected by the person who made the entry. All corrections will be initialed and dated.

6.0 EXPOSURE SCENARIOS

This section discusses steps to identify, screen, and develop exposure scenarios appropriate the BRMTS. These scenarios will provide a basis for evaluating the current potential exposures which may impact human health and the environment. The exposure scenarios developed for this document are a generalized description of the current land use conditions for the following sites based on available information.

- Desloge
- National
- Leadwood
- Elvins/Rivermines
- Bonne Terre
- Federal
- Doe Run
- Hayden Creek
- Big River Sediments

The amount of information available for the development of exposure scenarios differs for each site. When this document was prepared, the most detailed and complete information was available for the Desloge site. Very little information was available for the Hayden Creek site. As data is gathered for this RI, more information will be acquired for each site and the exposure scenarios will be refined and will become more site specific.

A generalized site conceptual model is presented in Figure 6-1. Each exposure scenario is comprised of the same components: a source of constituents of potential concern (COPCs), mechanisms that facilitate the transport of COPCs from the source through various environmental media, human potential receptors in the local environment, and a route of exposure for those receptors. Using these components, three steps were involved in developing the exposure scenarios:

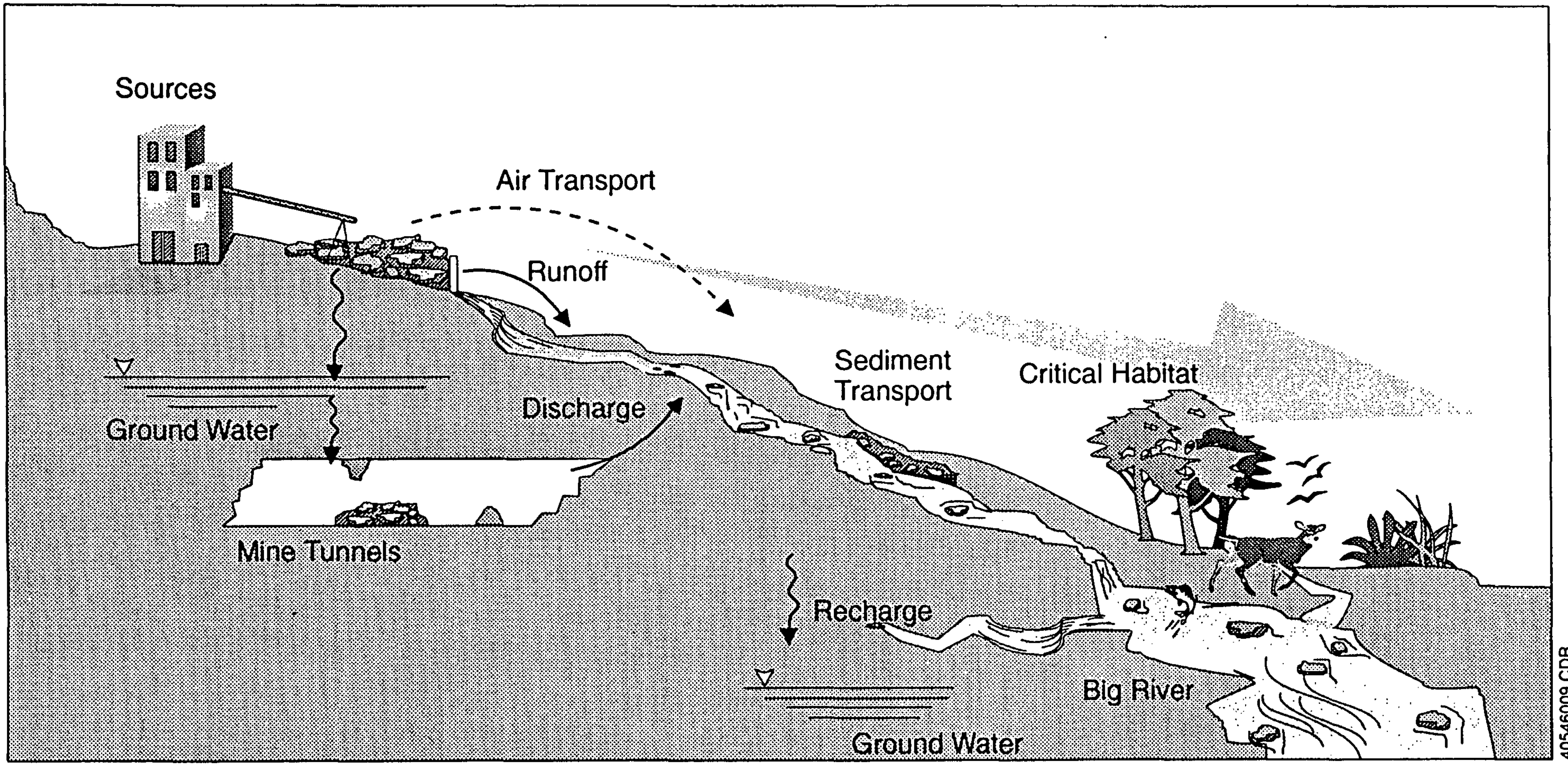


FIGURE 6-1
COMPONENTS OF THE SITE-WIDE CONCEPTUAL MODEL

1. Characterization of the exposure setting
2. Identification of potential exposure pathways
3. Selection of site-specific exposure pathways to be quantitatively evaluated.

6.1 Characterization of Exposure Setting

The development of appropriate exposure settings relied on the characteristics of the BRMTS and characterization information from previous environmental studies.

6.1.1 Physical Environment

The major features of the physical environment include the following features, which were described in Section 2.0:

- Topography
- Climate
- Geology
- Soils
- Sediments
- Surface water
- Groundwater
- Demography
- Ecology

6.1.2 Land Use

The current land use in the vicinity of the BRMTS ranges from urban to rural/agricultural. The most detailed land use information is available for the Desloge site. The on-site landfill employs four persons, and the asphalt contractor on the east end of the site employs from three to five. The residential area of the city of Desloge lies to the south and east of the site (ATSDR, 1994), and farmland is also reported east of the site. The National site is located in a residential/industrial area. The Federal and Leadwood sites are used by off-road vehicle riders.

The BRMTS are in the vicinity of several population centers. The city of Desloge, located southeast of the Desloge site, has a population of 4,227 (1990 census data). Desloge is one of several small towns separated only by political boundaries. The cities of Flat River, Rivermines, Elvins, and Esther were expected to join together in January 1994 to become Park Hills. Approximately two miles to the north of the Desloge site is the city of Bonne Terre, with a population of 4,004. Approximately two miles west of the Desloge site is the city of Leadwood, with a population of 1,156. Leadwood and Bonne Terre have tailings adjoining them, while the group of cities has tailings next to them or within a mile. The total population within approximately one mile of the tailings is 17,213 (ATSDR, 1994).

6.1.3 Potentially Exposed Populations

This section addresses human populations with potentially significant exposures to site-related contaminants. Hypothetical exposure scenarios have been developed to reflect reasonable estimates of human exposures which may occur within areas addressed in this RI. The following paragraphs provide details on the nature of the receptors and their respective pertinent exposure pathways.

Screening of Receptors and Exposure Pathways

Hypothetical exposures are assumed to occur at various locations, depending on the location of the tailings, as well as modeled concentrations of airborne particulate and compounds in surface water and groundwater. Receptor scenarios are described below.

Groundskeeper. In this scenario, it is assumed that a worker will be present on the property conducting groundskeeping and maintenance operations at each site. No groundwater exposure would occur within this scenario. On-site exposure pathways include inhalation of fugitive dusts and dermal contact with and incidental ingestion of soil, while on site.

Recreational Trespasser. This scenario evaluates the significance of exposures occurring while a trespasser wanders site lands for recreational purposes. It is assumed that this receptor ingests affected fish (fillet) from the Big River. Use of the sites by off-road vehicle riders will be evaluated, as appropriate. This individual is assumed to visit the sites despite continued private ownership. Exposure pathways addressed include the inhalation of fugitive dusts, dermal contact with and incidental ingestion of site soil, and incidental ingestion of Big River surface water and fish (fillet). The sites are assumed to remain property of The Doe Run Company; thus, site development for residential, farm, industrial/commercial or recreational (such as ball fields, jogging and biking trails) uses would not occur.

Off-Property Resident Farm Adult. Consistent with the reasonable maximum exposure (RME) concept and to ensure the estimated risk values protect human health and the environment, it was assumed that the current adjacent residential and agricultural uses would continue and that an adult farmer could reside adjacent to the sites.

Activities which may result in exposures include simply maintaining a residence in this area, growing food, tending livestock, and performing general farm work. These activities may result in direct dermal exposures (water and soil), inhalation of dust, incidental ingestion of soil, consumption of contaminated produce, dairy products, and meat, plus ingestion of affected Big River waters.

Off-Property Resident Farm Adult (Central Tendency). It is the policy of the EPA to present information on the range of exposures derived from exposure scenarios in developing human health risk assessments (EPA, Habicht Memo, 1992). The central tendency method will evaluate the farm adult exposure scenario using the less conservative central-tendency exposures as suggested by the EPA. The CT on-property farmer varies only in the exposure parameters which are chosen to be representative of typical median exposures. The central tendency (CT) on-property farmer has the same source terms, pathways, and exposure point concentrations as the on-property farmer.

Off-Property Resident Farm Child. Young children (age 1 through 6) living on the property would form a population of concern, because they may be more sensitive to a given exposure than are adults. A young child residing adjacent to the site could be exposed directly to site COPCs remaining in soils, and could inhale dust. In the risk evaluation, this hypothetical child of the on-property resident farm adult will be assumed to drink Big River water and to consume vegetables, fruit, meat, and dairy products produced from affected areas.

Big River User. This scenario was designed to evaluate the exposures occurring during the activities of a receptor who frequently uses the Big River for recreational purposes. Exposures evaluated will include the ingestion of fish caught in the Big River.

Selected Receptors and Scenarios

Six hypothetical receptors were selected to represent current land-use activities. Each receptor represents a unique population and exposure scenario. As a whole, they cover a wide range of exposure scenarios for potentially impacted human receptors. The six receptors are:

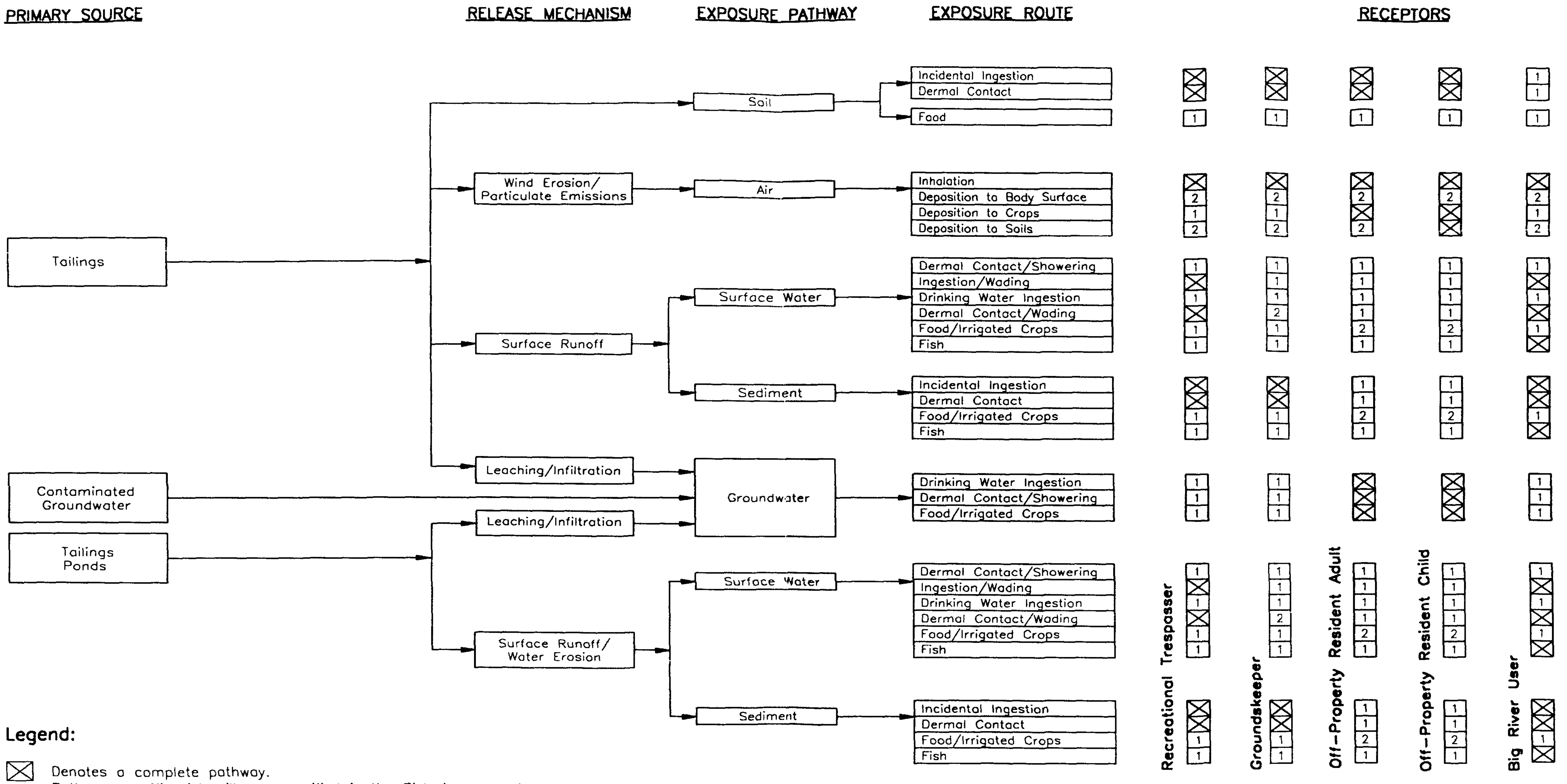
1. Groundskeeper
2. Recreational trespasser
3. Off-property resident farm adult
4. Off-property resident farm adult (central tendency)
5. Off-property resident farm child
6. Big River recreational user

Locations of Reasonable Maximum Exposure

Receptor locations will be selected based on the graphical representation of modeled air, soil, and water contaminant concentrations from current conditions. In keeping with the philosophy of evaluating the RME individual, the locations of highest on- and off-property exposures will be evaluated.

6.2 Detailed Conceptual Exposure Model

A detailed exposure conceptual model is presented as Figure 6-2. This model has been developed to provide the basis for identifying and evaluating the potential risk to human health during current use conditions. The key objective of the model is to facilitate the analysis of exposure routes and receptors, and focus on those pathways and sources that contribute most to the potential impacts on human health risk. It is also possible to screen out other exposure pathways that are likely to pose minor risks.



Legend:

☒ Denotes a complete pathway.
Pathway specific risk will be quantified in the Risk Assessment.

[1] Exposure route incomplete or not applicable.

[2] Potential impact of this exposure pathway is insignificant when compared to the other exposure pathways for the same receptor.

Note: This model would apply to each site.

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FIGURE 6-2
DETAILED EXPOSURE
CONCEPTUAL MODEL

The model provides a consistent and comprehensive evaluation of the risk to human health by creating a framework for identifying the mechanisms by which human health may be affected by the BRMTS. The elements necessary to construct a complete exposure pathway, and thus develop the conceptual model, are as follows:

- Sources of residual COPCs
- Release mechanisms
- Transport pathways
- Exposure routes
- Receptors

The model traces the exposure pathways from the sources through the release mechanisms and exposure routes to the affected receptors. The model also indicates which exposure routes will be carried through the quantitative risk assessment for each receptor.

6.2.1 Sources of Residual COPCs

Human-health risk will be evaluated under current use conditions. Figure 6-3 presents the current sources of COPCs and provides a basis for developing the exposure pathways in the conceptual model. The potential sources for each site include:

- Chat piles
- Fines
- Tailings ponds
- Mines
- Chat/fines/tailings run-off water
- Mills
- Boiler house
- Poor rock

The conceptual model addresses these sources as reservoirs of residual COPCs which may migrate to other environmental compartments or serve as a direct source of exposure.

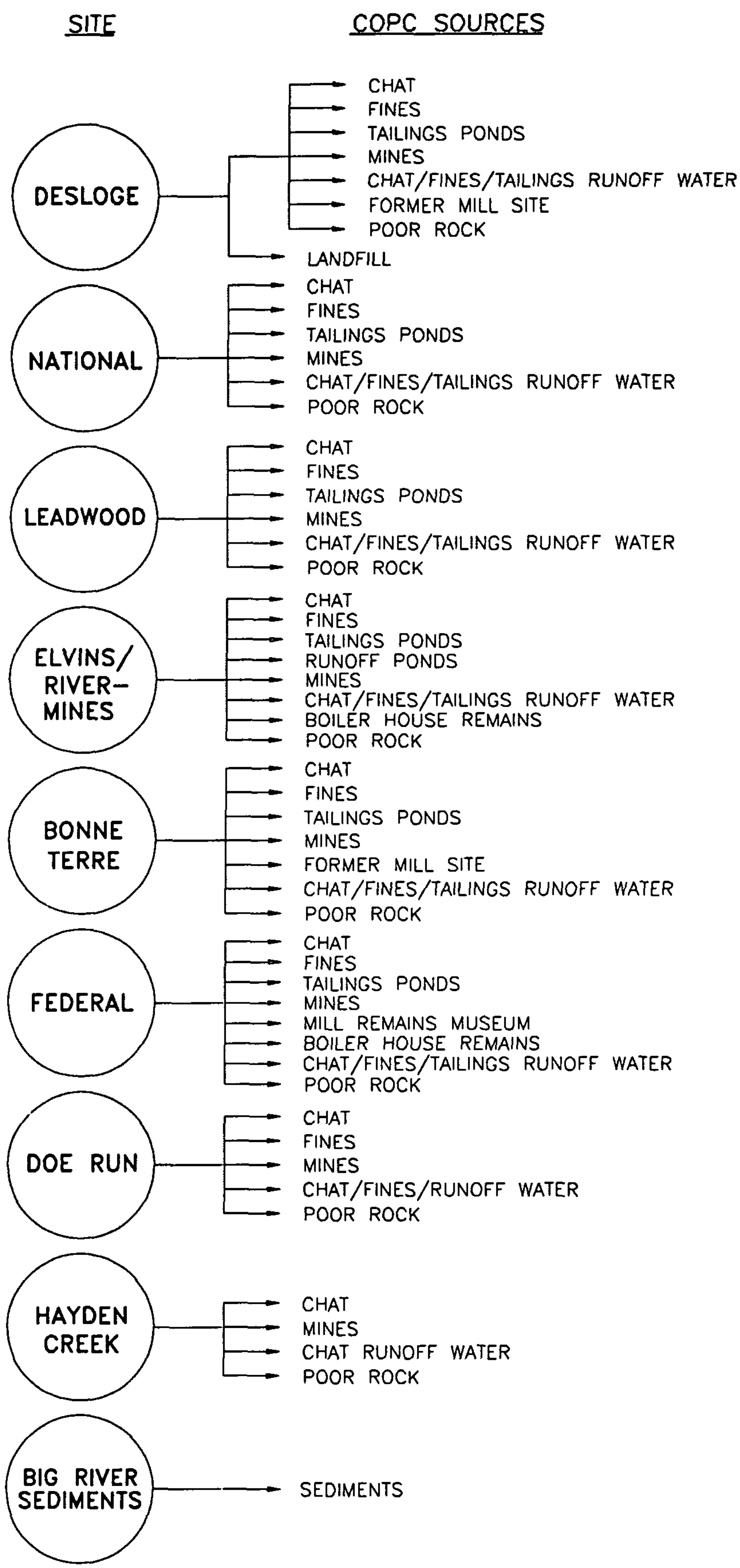

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FIGURE 6-3 OVERVIEW OF COPC SOURCES

6.2.2 Release Mechanisms of the Tailings

Large accumulations of tailings characterize these sites. Several mechanisms could allow these sources of COPCs to be accessed directly by a receptor or dispersed and made available for transport in the environment. Past releases of tailings have been observed to have been the result of wind erosion (dust clouds) and rainwater/surface water runoff erosion (1977 release to the Big River). Groundwater infiltration and contaminant leaching have also been a source of concern.

6.2.3 Transport of Source Emissions

Contaminated materials released from these sites can travel by several transport pathways to reach various environmental media to which potential receptors may be exposed. This section briefly discusses the four transport pathways.

Air

Releases to air may occur through the generation of inhalable particulates by wind or surface soil disturbance. Transport through the air has been observed to be a major pathway for COPCs in on-site tailings.

Surface Water and Sediment Runoff

Surface water transports tailings by conveying dissolved and suspended solids to receptors as it flows across the surface of the ground and along any surface drainage features. COPCs in the surface soils will be subject to transport in surface water/sediment runoff. Runoff can transport COPCs to receiving surface water bodies to which receptors may come in contact directly (through wading, etc.) or indirectly (through stock or irrigation water).

Leaching and Infiltration

A portion of on-site rainfall percolates through subsurface soil and recharges the underlying aquifer. Percolation would also occur through the porous tailings as a result of the natural weathering process. COPCs would be dissolved and transported in this flow and would eventually reach the aquifer. Dilution would also occur in the groundwater flow. Eventually, the groundwater could complete the pathway with transport to a well from which a receptor can take water for home and farm use.

6.2.4 Exposure Media

The transport pathways just discussed would result in the occurrence of site-related COPCs in various exposure media. The media to which receptors may be exposed include soil (either in-place residuals or materials transported from source areas by various mechanisms), groundwater, surface water, sediment, and air. Indirect human exposures to COPCs in one or more of these media may occur through the ingestion of crops or livestock and related products (meat, milk) which have been exposed to contaminated soil or water. In the case of on-property soil, no intermediate transport mechanism is necessary for on-property receptors; humans may be exposed directly to in-place materials.

6.3 Exposure Routes

There are three potential exposure routes by which receptors can come in contact with COPCs: ingestion, inhalation, and dermal contact. On the right-hand side of Figure 6-2, combinations of exposure pathways and exposure media are tabulated. Each pathway and medium are evaluated for each of the exposed receptors under the different exposure scenarios. Pathways identified as being complete and significant are denoted with an "X," while those not expected to result in significant exposures for a given receptor are noted, along with an explanation of why these pathways will not be included in the quantitative risk analysis for this initial RI.

6.3.1 Inhalation Route

A receptor's exposure via this route begins with wastes being transported by the ambient air, eventually reaching the receptor by inhalation. Inhalation of airborne resuspended particulate is a typical example of this type of exposure. The air exposure pathways are applicable to all on- and off-property receptors examined.

The significance of the air exposure pathway depends on the different characteristics of the receptor's daily activities. These pathways very often are receptor-specific. The significant air exposure pathways identified in this RI will include inhalation of resuspended particulate.

6.3.2 Exposures Attributable to the Dermal Contact Route

This route encompasses all of the receptor's activities that would result in direct contact with contaminated soil, sediment, and water. Potential sources of COPCs for these exposures include exposed soil, groundwater, and sediment.

Exposure pathways via dermal contact which will be considered in the quantitative risk assessment are dermal contact with soil and sediment. As in the inhalation exposure route, many dermal contact exposure routes are receptor-specific.

6.3.3 Ingestion Exposure Route

Direct ingestion of soil, sediment, drinking water, and food are considered plausible for many receptors. Ingestion of substances containing COPCs can come from direct or indirect routes. For example, a receptor may ingest COPCs from the aquifer in the drinking water, while wading in surface water, or by ingesting vegetation irrigated with contaminated water.

Eating meat or drinking milk from animals that have ingested contaminated soil, stock water, or foliage while grazing on adjacent property will be included in this risk analysis. Exposure routes such as ingestion of soil, surface water, sediment, groundwater, fish and crops are significant for the receptors investigated in this RI.

6.4 Metals Detected

A summary of metals detected in the environmental media at Desloge is presented in the table below. It was assumed for the purposes of developing the conceptual models in this section that the metals detected at Desloge were applicable to other BRMTS.

Metals Detected in the Environmental Media at Desloge*						
Lead	Tailings	Soil	Groundwater	Surface Water	Air	Biota
Cadmium	Tailings	Soil	Groundwater	Surface Water	Air	Biota
Zinc	Tailings	Soil	Groundwater	Surface Water	Air	Biota

*Should be applicable to other tailings sites

6.5 Ecological Risk Assessment

Ecological risk assessment is defined in the EPA's Framework for Ecological Risk Assessment (EPA, 1992) as a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors. A stressor is any physical, chemical, or biological entity that can induce an adverse ecological response. Adverse responses can range from sublethal chronic effects in an individual organism to a loss of ecosystem function. Although stressors can be biological (e.g., introduced species), only chemical or physical stressors will be addressed as these are the stressors likely to be encountered on the BRMTS.

As used in this document, the phrase "ecological risk assessment", refers to a qualitative and/or quantitative appraisal of the actual or potential impacts of a hazardous waste site on plants and animals other than humans and domesticated species (Ecological Risk Assessment Guidance for Superfund, EPA Review Draft, 1994). A risk does not exist unless: 1) the stressor has the ability to cause one or more adverse effects, and 2) it occurs with or contacts an ecological component long enough and at a sufficient intensity to elicit the identified adverse effect. The specific objectives of this process, as stated in OSWER Directive 9285.7-17, are: 1) to identify and characterize the current and potential threats to the environment from a hazardous substance release, and 2) to establish clean-up levels that will protect those natural resources at risk. The functions of the ecological risk assessment are to:

- Document whether actual or potential ecological risk exists at a site

- Screen the COPCs present at a site for those that might pose an ecological risk, thereby focusing further efforts

- Generate data to be used in evaluating clean-up options.

The following eight steps summarize the ecological risk assessment process:

1. Preliminary problem formulation and ecological effects evaluation

2. Preliminary exposure estimate and risk calculation

3. Problem formulation, including assessment endpoints and a testable hypothesis

4. Conceptual model development, including endpoint selection and study design

5. Site assessment to confirm the ecological sampling and analysis plan

6. Site field investigation

7. Risk characterization

8. Risk management

For the BRMTS, this document will address steps one and two of the ecological risk assessment process.

A preliminary problem formulation and ecological effects evaluation is part of the initial ecological risk screening assessment. In this step it is assumed that limited information is available for site characterization, as well as for determining the extent and nature of contamination. This step includes all the functions of problem formulation (more fully described in Steps 3 and 4) and ecological effects analysis, but on a screening level. The results of this step will be used in conjunction with exposure estimates in the preliminary risk calculation in Step 2.

Problem formulation focuses on four issues:

1. Environmental setting and COPCs known or suspected to exist at the site

2. COPC fate and transport mechanisms that may exist at the site

3. The toxic mechanism associated with each COPC and categories of receptors likely to be affected

4. The complete exposure pathways that may exist at the site. (A complete exposure route is one in which the COPC can be traced from the source to the receptor being evaluated.)

The evaluation of the ecological effects associated with the COPCs documented or anticipated at the site includes development of a toxicity profile and screening ecotoxicity value for those chemicals. A literature search of studies that evaluate the toxicity (target tissue and dose-response) and toxic mechanisms of chemicals is necessary to evaluate the likelihood of toxic effects. The toxicity profile should describe the toxic mechanisms of action for the exposure route being evaluated and the dose or environmental concentration that causes a specified adverse effect. For each complete exposure route, a screening-level ecotoxicity value, or benchmark, should be developed. For each complete exposure route, the literature should be reviewed for the lowest exposure level (e.g., concentration in water or in the diet, ingested dose) shown to produce adverse effects (e.g., reduced growth, impaired reproduction, increased mortality) in a potential receptor species (i.e., a lowest-observed-adverse-effect level or LOAEL). In addition, the highest exposure level at which no adverse effects have been demonstrated (no-observed-adverse-effect level or NOAEL) should be identified. A NOAEL is more appropriate than a LOAEL for the initial screening assessment to ensure that risk is not underestimated. However, NOAELs are not currently available for many wildlife species or many chemicals. In some cases, toxicity data from a related species can be used to estimate a NOAEL for a receptor species. When a NOAEL value is not available but a LOAEL is obtained from the literature, the standard practice is to multiply the LOAEL by 0.1 to estimate the NOAEL.

The exposure estimate and preliminary risk calculation comprise the second step in the ecological risk screening for a site. Risk is estimated by comparing maximum likely exposure levels with the screening-level ecotoxicity values from Step 1. At the conclusion of this step, it will be decided that either: 1) the site preliminary screening is adequate to determine that there is little or no ecological threat, or 2) the ecological risk assessment should continue.

The preliminary risk calculation can be performed using the screening-level ecotoxicity values derived in Step 1 and the exposure levels estimated in this step. The risk calculation consists of comparing the exposure estimate to the screening ecotoxicity value using the hazard quotient method. The preliminary risk calculation should include:

- A description of the complete exposure route(s) or lack thereof
- The result of the hazard quotient calculation
- A discussion of the uncertainty of the hazard quotient
- A summary of the overall confidence in the assessment.

For the purposes of the preliminary risk calculation, conservative assumptions will be used. It is important to note that the decision made at the end of the preliminary risk calculation will not set a clean-up goal. Instead, one of the following will be decided:

- The ecological risk assessment should be continued to develop a site-specific clean-up goal or to reduce uncertainty in the evaluation of no risk

- The preliminary screening is adequate to determine that little or no ecological risk exists.

To estimate exposure for the preliminary ecological risk calculation, COPC levels on site and general information on the types of biological receptors present or anticipated on site should be known. Only complete exposure pathways should be evaluated. For these, the highest measured or estimated on-site COPC concentration on a medium-by-medium basis should be used to calculate exposures to ensure that potential ecological threats will not be missed.

Some of the conservative assumptions used in the preliminary exposure estimate (in the absence of sound site-specific information) are described below. Specifically, these assumptions are:

- Area-use factor, 100 percent (related to home range)
- Bioavailability, 100 percent
- Sensitive life stage, use of most sensitive life stage
- Body weight, minimum body weight to maximum ingestion rate

A quantitative screening risk value can be calculated using exposure estimates and the screening ecotoxicity values developed above. Although several approaches can be used to estimate risk for the preliminary risk calculation, the hazard quotient method comparing single effect and exposure values is adequate.

The hazard quotient method compares the estimated exposure levels to the measured or predicted threshold value for effects, e.g., NOAEL for acute or chronic toxicity (EPA, 1989b). As described in Step 1, for the screening ecological risk assessment, the ecotoxicity threshold value should be based on the documented and/or best conservatively estimated NOAEL.

A hazard quotient is expressed at the ratio of a potential exposure level to the ecotoxicity screening value:

$$HQ = \frac{\text{Dose}}{\text{NOAEL}} \quad \text{or} \quad HQ = \frac{\text{EEC}}{\text{NOAEL}}$$

where:

HQ	=	hazard quotient,
Dose	=	estimated contaminant intake (mg/kg-day)
EEC	=	estimated environmental concentration (mg/L water), and
NOAEL	=	no-observed-adverse-effect level (in units that match the dose or EEC).

A hazard quotient greater than 1 is interpreted as a level at which adverse ecological effects are likely to occur. A hazard quotient less than 1 does not indicate a lack of risk, but should be interpreted based on the severity of the effect reported and the magnitude of the calculated quotient. As certainty in the exposure concentrations and the NOAEL increase, there is greater confidence in the predictive value of the hazard quotient model, and unity (HQ=1) becomes a pass/fail decision point. If multiple ecological COPCs exist at the site, it may be appropriate to sum the HQs for COPCs with the same ecological effect endpoint and/or the same mechanism of toxic effect. When it is appropriate to sum the HQs, the HQ summation should not exceed 1.

The preliminary risk calculation is a conservative estimate to ensure that potential ecological threats will not be overlooked. The calculation is used to document a decision about whether or not there is a negligible potential for ecological impacts based on the information available at this stage.

The result of the preliminary ecological risk calculation step will determine if there is adequate information available regarding the site and its COPCs to complete the ecological risk assessment at this step. The lead risk manager and lead assessor will determine if there is little or no ecological threat related to the site. If this is the case, the ecological risk assessment will be complete at this step. If not, the ecological risk assessment will continue to refine the problem formulation in Step 3.

The intent of this step is not to derive a "reasonable" exposure. Steps 3 through 8 are the guidance for developing a reasonable exposure and for developing a site-specific cleanup goal based on the exposure. The uncertainty inherent in the preliminary risk assessment step is biased conservatively both in the area-use factors and the site-specific contamination. Conservative assumptions have been used for each step of the preliminary ecological risk assessment. Therefore, requiring a cleanup based solely on this information would not be technically defensible. The preliminary risk calculation must be able to adequately document a decision that there is a negligible or no ecological risk and that the preliminary risk calculation is an adequate ecological risk assessment. A lack of information on the toxicity of a chemical or on a complete exposure route will result in decision to continue with the Steps 3 through 8 of the ecological risk assessment process.

6.6 Ecological Risk Screening for the BRMTS

The pending ecological risk assessment for the BRMTS was the subject of the Big River Biology Technical Advisory Group (BTAG) meeting held on March 1, 1995, in Missouri. The attendees included representatives of The Doe Run Company and its consultants Fluor Daniel and EMS, as well as the MDOH, MDNR-DGLS, MDNR-HWP, Missouri Department of Conservation, St. Francois County Health Department, EPA, EPA/ERT, U.S. Fish and Wildlife Service, and USFWS/ERT.

For the Old Lead Belt, a group consensus for the following issues was reached as a starting point for the ecological risk assessment.

Regulatory Guidelines for the BRMTS Ecological Risk Assessment

The ecological risk assessment for the BRMTS will follow the EPA guidelines as stated in the Review Draft of the Ecological Risk Assessment Guidance for Superfund (September 26, 1994) which was briefly described in Section 6.5

Scope of First Report

The first document to be prepared as part of the ecological risk assessment will consist of steps one and two of the eight-step process outlined by EPA. A preliminary problem formulation and ecological effects evaluation will be performed. A preliminary screening exposure estimate and risk calculation will be developed.

Focus of Ecological Risk Assessment

The BRMTS as defined in Section 6.1 will be the focus of the risk assessment. The current baseline conditions will be evaluated.

Constituents of Potential Concern

The COPCs for the BRMTS will be lead, cadmium, and zinc as defined by EPA in its preliminary site investigation documents. As a conservative assumption for the screening exposure assessment and risk calculation, the effect of the highest metal concentrations in all evaluated exposure media and pathways will be evaluated.

Terrestrial Species Risk Screening

The terrestrial species food web that will be evaluated in this risk assessment is shown in Figure 6-4. This figure shows representative trophic levels leading to the redtail hawk, which was chosen the target species for the terrestrial ecosystem. As the selected top predator in the food web, the redtail hawk will be exposed to metals through ingestion of primary consumers. The metal uptake for each level in the food web leading to the redtail hawk will be estimated assuming maximum metal exposures through the trophic levels.

Aquatic Species Risk Screening

The aquatic species food web that will be evaluated in this risk assessment is shown as Figure 6-5. This figure shows representative trophic levels leading to the mink and great blue heron (which are the top predators) and the pink mucket pearly mussel (which is a representative filter-feeding mollusc exposed to metal-affected sediments). The metal uptake for each level in the food web leading to the mink, blue heron, or mussel will be estimated assuming maximum exposure through the next lower trophic level.

The following is a list of species-specific information needed for the ecological risk screening:

1. Mink, Fox, Redtail Hawk Great Blue Heron
    - NOAELs
    - Ingestion rates
        - Food
        - Water
        - Dirt
    - Inhalation rates

2. Earthworm
    - Metal concentration

3. Shrew
    - Ingestion rate
        - Food
        - Water
        - Dirt
    - Absorption rates
    - Inhalation rates

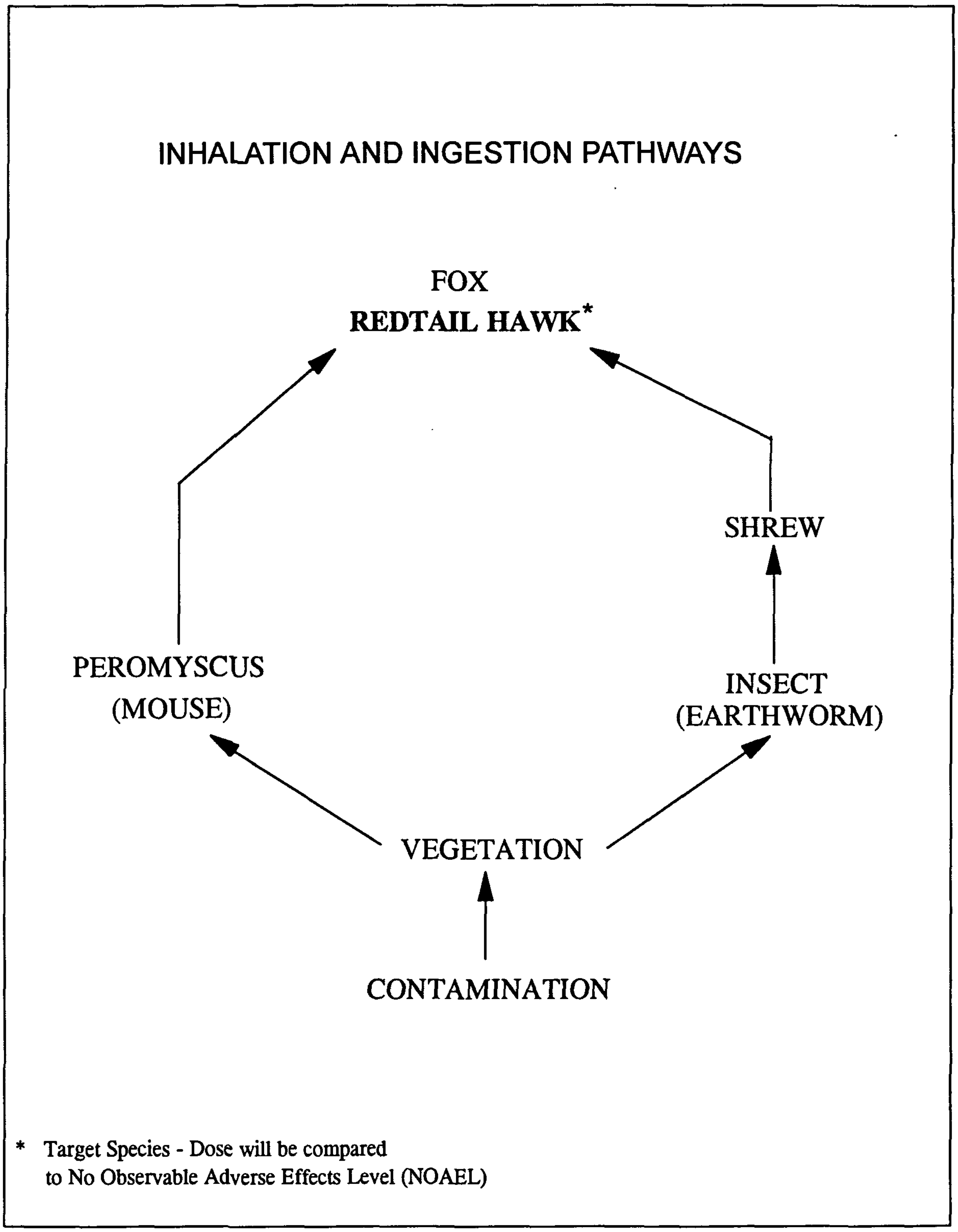

FIGURE 6-4

BRMTS TERRESTRIAL SPECIES RISK SCREENING

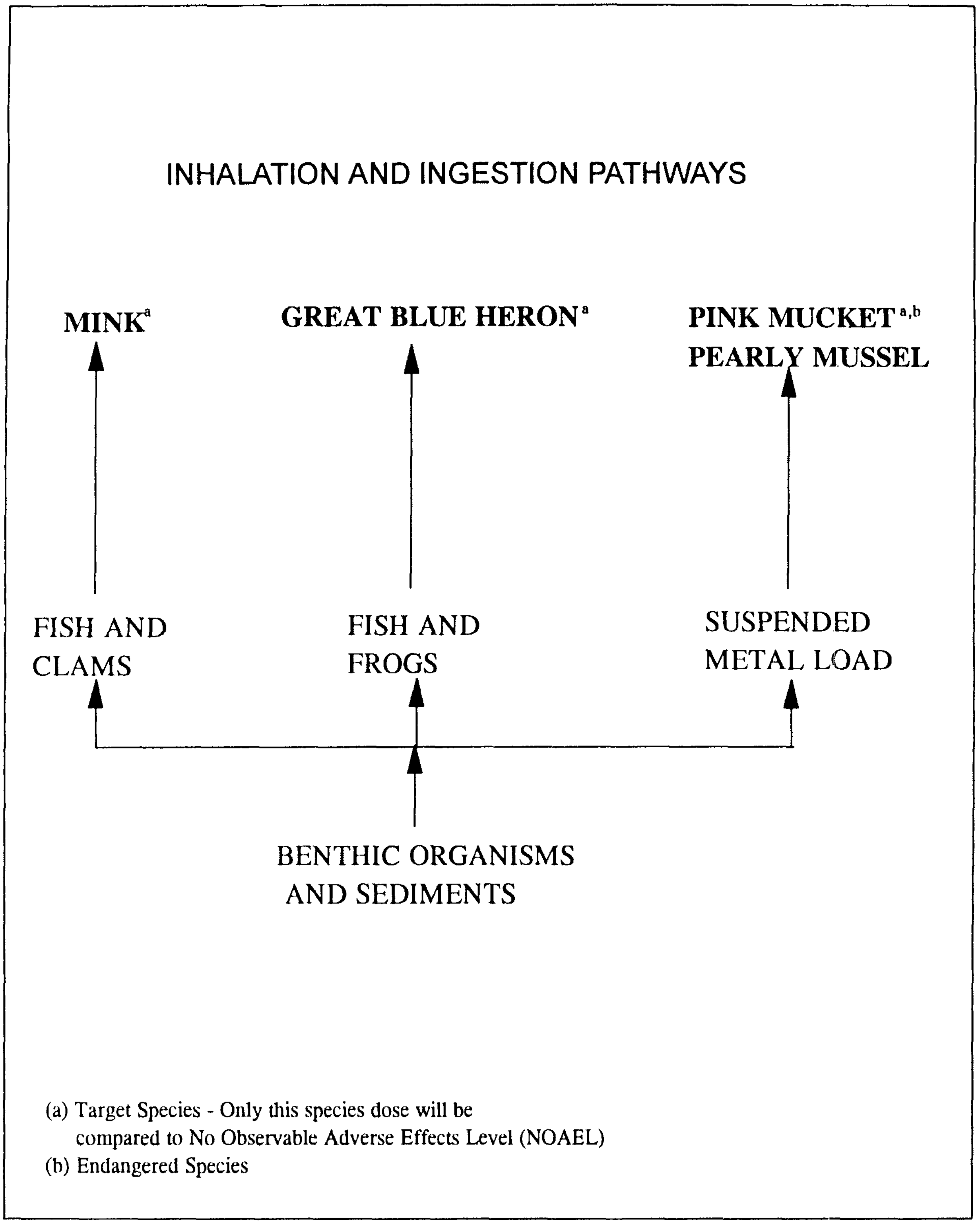

FIGURE 6-5

BRMTS AQUATIC SPECIES RISK SCREENING

4. Mussel
   - NOAEL
   - Dose
     - Amount of water filtered
     - Concentration of suspended metals (lowest sfn)
     - Absorption rate

Also needed are the maximum exposure point concentrations of lead, cadmium, and zinc for each contaminant source (i.e., tailings, soils, sediments, river water, and air).

7.0 CONCLUSIONS AND RECOMMENDATIONS

From 1972 to 1995, many agencies and institutions investigated the mining sites in the Old Lead Belt of St. Francois County, Missouri. The data from these investigations has been compiled, reviewed, and evaluated in this initial RI report. The purpose of this effort was to:

- Determine if the mine tailings have been adequately described, both physically and chemically
- Select chemicals of potential concern
- Determine if more information is needed to eliminate "gaps" in the existing set of data
- Determine if the risks to human health and the environment can be calculated from the exiting data
- Determine if near-term, interim actions are needed to stabilize the tailings to minimize erosion.

As part of this RI, the collected data was compared to the above objectives, resulting in the following conclusions (Section 7.1) and recommendations (Section 7.2).

7.1 Conclusions

This initial RI was conducted to compile and evaluate information from previous investigations and research related to the Old Lead Belt, Big River, and mine tailings in St. Francois County, Missouri. Appendix A presents the results of this compilation, that is, those studies containing accurate, complete, and verifiable data. Data was considered only if it satisfies the EPA's data quality objectives for use in assessing the presence of constituents. Based on this data, the extent of certain constituents deemed to pose "potential concern" was determined. These "constituents of potential concern" (COPCs) were evaluated in the various environmental media: air, surface water, groundwater, soil, and biota. With regard to the objectives of this initial RI, the following conclusions are offered.

Nine Big River Mine Tailings Sites have been Identified

A history of the Old Lead Belt was developed using historical maps, photographs, and interviews with knowledgeable individuals. Based on this effort, the following nine sites were identified:

- Desloge
- National
- Leadwood
- Elvins/Rivermines
- Bonne Terre
- Federal
- Doe Run
- Hayden Creek
- Big River Sediments

Mine Tailings have been Quantified

Mine tailings are easily identified from color aerial photographs because their distinct white color contrasts greatly with the surrounding red surface soils. The BRMTS tailings have been identified and the acreage and volumes estimated. In addition, the mean and maximum concentrations of the COPCs in the tailings have been determined. Two sites, Doe Run and Hayden Creek, do not appear to have extensive tailings deposits but may contain remnants in the soil.

Lead, Cadmium, and Zinc are the Chemicals of Potential Concern

The selection of the COPCs for this RI began by reviewing the 24 metals tested for in the tailings during previous studies. Of the 24 metals, only 17 were detected. The maximum concentrations of the 17 detected metals were then screened for selection of the COPCs. Essential nutrients, constituents with concentrations less than natural background levels, and those for which the EPA does not have toxicological information were dropped from consideration. The results of this selection process (detailed in Section 4.1) indicate that lead, cadmium, and zinc are the three COPCs.

This summer, in cooperation with the ATSDR, the MDOH will begin testing the blood-lead levels of residents in the Old Lead Belt, and the lead levels in the drinking water, soils, interior dust, and other environmental samples at 300 homes. The results of this sampling, and any additional field sampling and analysis proposed in this RI, will be reviewed for impact to the COPC selections. The selection of lead, cadmium, and zinc as COPCs also reflects the recommendations of several EPA investigations and was discussed at a meeting on March 1, 1995, with the Biological Technical Assistance Group (BTAG), whose members include the EPA, MDNR, MDOH, and U.S. Fish and Wildlife Service (USFWS).

Baseline Conditions of the BRMTS are Well Understood

The history of the Old Lead Belt is well understood, and information has been traced back to the 1700s for this effort. Historical maps and photographs were available to determine operations, tailings disposal, and smelter locations for each of the sites. Some information on Doe Run and Hayden Creek will need to be supplemented with sampling data to determine the residual concentrations of COPCs in the soils. The tailings have been sampled repeatedly over the past 14 years. The metal content of the tailings is well understood, and the selection of lead, cadmium, and zinc as COPCs is well founded. Furthermore, any action taken to contain the lead, cadmium, and zinc would also bind or contain the lesser contributions of the other, trace metals in the tailings.

While elevated concentrations of lead, cadmium, and zinc have been identified, the potential human health risk of these concentrations will be estimated by the baseline human health risk assessment. The risk assessment will be conducted after the MDOH completes its field sampling program this summer and will incorporate its results. The scope will include discussions of the potential users of the sites ("receptors" of COPCs), possible routes of exposure and human intake, and the bioavailability of the three COPCs. The information collected will be reviewed for the possible inclusion of other COPCs.

Soils. Data on metals in the soil has been collected through several investigations that indicate elevated levels of the COPCs. This data will be supplemented by the field sampling program to be conducted this year by The Doe Run Company (see Section 5.5) and by the blood lead and environmental sampling to be performed by MDOH. Upon review of this information, the baseline human health risk assessment and an ecological risk screening will be completed. The studies will assess the potential exposure of the human population and the ecosystem to on- and off-site soils under existing conditions and a "no-remedial-action" future scenario.

Surface Water. COPCs have been documented in the sediments of the Big River and to a lesser extent in its surface water, but not above any applicable or relevant and appropriate requirements (ARARs). The results of the surface water analyses will be used in the baseline human health risk assessment and the ecological risk screening to determine the extent of risk from COPCs in the water.

Drinking Water and Groundwater. As previously noted, the MDOH will sample the drinking water of 300 homes in the Old Lead Belt this summer. COPC concentrations measured to date have been primarily below drinking water standards. A 1994 ATSDR-sponsored report (MDOH, 1994) indicates that the levels of lead in drinking water are near a federal action level. One confounding consideration is that lead-pipe plumbing appears to be quite common in the area. The MDOH field sampling program will also gather data on lead pipes and drinking water concentrations before and after the entry point of water into the home and from the tap. After the MDOH program has been completed and its results evaluated, additional groundwater considerations will be evaluated. The drinking water samples obtained by MDOH this summer will be compared to the EPA's drinking water action levels (greater than 0.015 mg/l lead, an MCL of 0.005 mg/l cadmium, and 5.0 mg/l zinc).

Sediments. The sediments within the Big River are well defined with regard to the COPCs. The dredging of sediments to capture the COPCs may cause the re-suspension of the sediments in the water column, and could move the COPCs further down river. This initial RI focused on the information needed to protect the tailings from wind and surface water erosion. Next, the need to address lesser concentrations of COPCs in surface soils, surface water, and groundwater will be assessed based on the results of the baseline human health risk assessment and the 1995 field sampling programs. The anticipated field sampling programs include:

- MDOH blood-lead and environmental sampling
- The Doe Run Company field sampling program (Section 5.5 of this RI)
- Stormwater and vegetation studies underway for Desloge interim action

Air Quality. Air Quality monitoring in and around Desloge has been completed for total suspended particulate (TSP), and the sampling did not identify TSP above any federal or state air quality standard. When the TSP monitoring was conducted (in the early 1980s), TSP was considered the valid national ambient air quality standard (NAAQS). The TSP standard has since been replaced by the inhalable particulate standard of 10 microns or less, otherwise known as PM-10. Since the inhalation of dust is a key pathway for human and ecological receptors, it is important to obtain PM-10 information. For the purposes of the risk assessment, PM-10 air monitoring will be completed as part of The Doe Run Company's field sampling program (see Section 5.5).

Receptors. Receptors are "typical" individuals who are potentially at risk from exposure to COPCs. Potential BRMTS receptors include persons living on and off site, including residents living at the fence line, recreational users (such as dirt bike riders), and transients passing through the sites. The ecological risk screening will determine the need for an ecological risk assessment of biological endpoints in the aquatic, terrestrial, and wetlands habitats.

Biota (Flora and Fauna). COPCs have been detected in vegetation and aquatic species in the Big River. On-site terrestrial species have not been well documented and are proposed to be studied and sampled this summer. The ecological risk screening for aquatic and terrestrial habitats will further define the need for additional field sampling and study of biota.

A Formal Risk Assessment is Needed to Estimate the Current Risk to Human Health

Upon collection and analysis of the data from this summer's field sampling programs (MDOH and The Doe Run Company), and after the new data is incorporated into the RI, then a baseline human health risk assessment will be prepared in accordance with the EPA's Risk Assessment Guidance for Superfund (RAGS, EPA, 1990). The assumptions, exposures, and input to be used for this risk assessment will be detailed in a work plan and will reflect the input of the EPA, MDNR, and MDOH.

Evaluate and Incorporate the Results of the Ongoing Ecological Risk Screening

The Doe Run Company and its representatives met with EPA Region VII, MDNR, MDOH, U.S. Geological Survey (USGS), MDOH, and USFWS on March 1, 1995, in St. Francois County. At this meeting, it was agreed that an ecological risk screening would be completed in April 1995. The purpose of the screening study is to determine, using conservative parameters, whether further ecological risk assessment is justified. It was also decided at the meeting that the COPCs for ecological risk screening would be lead, cadmium, and zinc. The aquatic and terrestrial biological endpoints to be compared to the no-observed-adverse-effects levels (NOAELs) are described in Section 5.5.5.

Source Data is Essentially Complete

The conclusion of this RI is that the characterization of the tailings is essentially complete. One exception is that specific data is needed to perform the human health risk assessment. For the risk assessment, the just the top six inches of tailings would be need to be sampled to assess the potential risk due to dermal absorption of the COPCs. Other data gaps should be eliminated using data from this summer's sampling programs. The MDOH program will collect blood-lead data on residents and environmental samples from soils, drinking water, and in-home dust. This data and field sampling and analysis to be obtained by The Doe Run Company will provide information needed to fill the data needs listed in Section 5.0.

7.2 Recommendations

Based on the review and analysis of previous Old Lead Belt investigations (see Sections 2.0 through 5.0), certain "gaps" in the existing data set have been identified (Section 5.4). In response, this summer the MDOH will complete a human-health and environmental sampling and analysis program involving 300 homes in the Old Lead Belt, and The Doe Run Company will initiate field sampling and analyses. The results of the two investigations will be summarized and used to supplement this RI. Specifically, the following tasks should be performed:

- Incorporate the data from this summer's field sampling programs conducted by MDOH and The Doe Run Company
- Perform additional field sampling and analyses; incorporate results
- Complete the baseline human health risk assessment; incorporate results
- Complete the ecological risk screening; incorporate results
- Add bioavailablity research of lead and results of on-site blood-lead tests from other sites

Consider the Data Generated on the Tailings to be Complete

The tailings in St. Francois County originated from the extraction of lead from the same subsurface deposit. The tailings have been subject to hundreds of sampling events, producing a range of COPC concentrations that vary primarily as a function of the location of the sample in the exterior or interior of the tailings piles. Therefore, it is recommended that the top six inches of the tailings piles be analyzed for the COPCs. This will produce the specific "characterization" data needed for the human health risk assessment, to properly estimate the exposure to receptors. No other sampling of the tailings is recommended.

Cut Off Wind Erosion and Surface Water Contact with the Tailings

The tailings at the individual sites are a source of COPCs to the air (as fugitive dust) and to the surface water (as run off from rainfall). In the near term, the piles should first be contained and then stabilized to eliminate existing and potential future sources and reduce overall erosion. The impact of blocking these sources can be monitored in the Big River and with downwind measurements of airborne particulate (PM-10).

Perform Studies to Supplement the Knowledge Base of Stabilization

To support stabilization of the tailings, various mechanical, physical, and vegetative methods will be reviewed or tested. The use of these interim remedial measures will be evaluated in light of their potential to increase risk through their implementation.

Complete the Baseline Human Health Risk Assessment

Elevated levels of COPCs have been identified in various environmental media, and it is therefore necessary under CERCLA to estimate the potential effects of existing conditions for a series of potential site users ("receptors"). As indicated under CERCLA, the selected remedy must be compared on a risk basis to the "no-action" alternative to demonstrate that implementing the remedy would not present greater risk than taking no action. With the inclusion of the baseline human health risk assessment and subsequent field sampling and analyses, this initial RI would become the final RI document and provide the foundation for the Feasibility Study (FS).

- Integrate the Field Sampling Results into the RI

It is essential that this summer's field testing by the MDOH and the sampling and analysis to be commissioned by The Doe Run Company be accurately integrated into the RI and, more specifically, into the Graphic Information System (GIS). To create accurate, easy-to-use graphic plots of residents' blood-lead concentrations, residential soil and drinking water COPC concentrations, and lead-paint concentrations, then the exact locations of the sampling points and the homes must be accurately documented and completely reproducible. As such, it is recommended that as sampling plans are developed and implemented, the sampling locations be entered into the GIS database for use in revising this RI and in performing the baseline human health risk assessment. Both the MDOH and The Doe Run Company's sampling efforts should be coordinated using this system.

Implement a Full-Scale Graphic Information System

This initial RI represents a first attempt at consolidating the information available on the BRMTS into a GIS. Previous investigations have provided generalized information on sampling locations, but without specific point locations for the sampling, plotting the exact COPC concentrations is difficult (and time consuming).

For this RI, a GIS base map of the BRMTS was developed to provide a mechanism for easily maintaining, validating, summarizing, and presenting the results of future RI/FS activities. Figures presented in this document were created from the base map. As part of the focused RI, data from field sampling activities will be formatted and recorded in the GIS, and further research will be performed to more accurately locate existing validated data for incorporation in the GIS. When sampling data is generated (chemistry, geology, hydrology, etc.), it will be entered into the database tied directly to the sampling locations.

The GIS is AutoCAD-based, using GIS/Key and AutoCAD Data Extension software. In addition to generating concentration contours, graphs, and reports, the selected system will execute automatic quality control checking of data, checking against action levels, and user alerts. Graphs include Constituent versus Time, Site versus Site, and Constituent versus Depth.

Tailings Piles and Residual Material can be Distinguished by Color

Additional aerial photographs for the tailings and surrounding areas should be obtained to differentiate the various off-site tailings in the neighboring soils. As mentioned before, the differences are easily made based on color interpretation.

The Area-Wide Approach to the BRMTS RI is Sound

In summary, the tailings piles currently represent a replenishing source of COPCs to the environment. Throughout St. Francois County, the tailings are essentially the same, containing the same COPCs, differing only in pile size and shape. The BRMTS should therefore be addressed on an area-wide basis, since the same materials--and COPCs--are present at all sites.

The release of COPCs to the environment will decrease with the stabilization of the tailings as wind and rain erosion are minimized. Accommodating the need for completing a series of interim remedial measures (IRMs) to stabilize the tailings piles and prevent further erosion is recommended. Upon completion of the IRMs and the collection of the field sampling and analysis this summer, the RI would then use the completed IRMs as the starting point for baseline conditions. However, disturbing either the tailings or Big River sediments to retrieve COPCs may mean using dispersing actions that would entrain the COPCs in the air or water. This could cause potentially greater risk to human health and the environment than would simple stabilization and continued monitoring. Therefore, no additional remedial actions (other than stabilization) are recommended until the baseline human health risk assessment and the ecological risk screening are completed.

Finally, the results of the MDOH blood-lead and environmental sampling and analysis will allow the mapping of any areas where higher blood-lead levels are documented. This mapping could then be used to prioritize further cleanup, retrieval, or containment activities.

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APPENDIX A

ANALYSIS
OF
ENVIRONMENTAL DATA

INITIAL REMEDIAL INVESTIGATION
BIG RIVER MINE TAILINGS SITES
ST. FRANCOIS COUNTY, MISSOURI

DRAFT
APRIL 1995

APPENDIX A - ANALYSIS OF ENVIRONMENTAL DATA

From 1972 to 1995, several site studies were conducted at the Big River Mine Tailings Sites (BRMTS) and the Big River. The investigations of the BRMTS have focussed on the Desloge tailings piles and the surrounding area but include data for piles at other locations such as Leadwood, Federal, and Elvins. The tailings at Desloge consist of the same material found at the other sites. Information on the remaining sites includes data from water/sediment samples that have been collected from the Big River. Other studies on tailings piles elsewhere in the Old Lead Belt have been researched, reviewed and incorporated. A review of the available literature has revealed the following sources of information.

One of the objectives of this initial RI was to identify existing data and information that can be used in the second phase of the RI process. Existing data required to perform an RI was reviewed for both the BRMTS and the Big River. This data was extracted from previous studies performed in the area. Existing data required to perform an RI was reviewed for both the Old Lead Belt and specific sites. The following pages identify studies which have been reviewed and contain data relevant to the RI/FS process. Appendix A presents the raw data in the form of tables and summary text which was used in this RI. As new data become available from field sampling efforts, it will be summarized and incorporated into this appendix and other sections of this RI report.

120.2.1R Control of Mine Tailing Discharges to Big River, MDNR, 1980

This report indicates that the tailings pile at Desloge was sampled. The sampling distinguished between clay and sand. The sampling and analyses encompassed 24 metals:

- Aluminum
- Barium
- Beryllium
- Boron
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Lithium
- Magnesium
- Manganese
- Molybdenum
- Nickel
- Phosphorus
- Potassium
- Silver
- Sodium
- Strontium
- Titanium
- Vanadium
- Zinc

Of these 24 metals, 17 were detected: Al, B, Ba, Ca, Cd, Co, Cu, Fe, Mg, Mn, Na, Ni, P, Pb, Sr, Zn and K. Table A-1 provides sampled data for Constituents of Potential Concern (MDNR, 1980).

The report provides history, locations, photographs, and particle size fraction information circa 1980 from leachate.

TABLE A-1
METALS IN LEACHATE SAMPLES AT DESLOGE

	Clay (μg/g dry)			Sand (μg/g dry)		
Metal	Water	EDTA	HNO_3	Water	EDTA	HNO_3
Lead	20	2,200	2,400	26	720	850
Cadmium	ND	3.2	14	ND	5.8	25
Zinc	3.4	220	680	14	230	1,000
Cobalt	ND	20	41	ND	89	11
Nickel	ND	8.2	45	ND	3.4	16

Note:
ND = Not detected Water = Rainfall through tailings
EDTA = Ethylenediaminetetraacetic acid and represents landfill leachate through tailings.
HNO_3 = Total metal content in tailings

120.2.2R Lead Studies on Fish, Mussels and Sediments in Big River of Southeast Missouri, May 1985

Discusses exclusively fish tissue data for lead data at Leadwood, National, and Bonne Terre. Table A-2 presents the data. Review of this information indicates that fish tissue concentrations of lead are elevated in the Big River. This report presents results of the investigation on the concentration of lead in sediment, fish filets, intestines and the soft tissues of the asiatic clam (Corbicula leana) collected in 1983-1985 from the Big River.

Longear sunfish and two species of suckers (northern hogsucker and black redhorse sucker) were collected in 1983 and 1984 and were prepared for lead analyses. As with previous investigations, the lead concentration was higher in suckers than in the longear sunfish, with the concentration in filets of suckers exceeding the World Health Organization (WHO) lead limit of

0.3 ppm (μg/g) at most sites affect by tailings. Mean lead concentrations in longear sunfish filets (0.310 ppm) exceed the WHO limit at the Flat River Creek Site in 1983 and the Flat River Creek (0.439 ppm) and Washington State Park (0.565 ppm) sites in 1984. *Corbicula* species were collected at five sampling sites in the Big River in 1985. Lead concentrations in this clam were found to be highly variable in specimens collected from contaminated sites, with some specimens below the Eaton Creek confluence having lead concentrations in excess of 7000 ppm. The authors of this report indicated that the variability and the high lead concentrations could be attributed to residual sediments or debris within the gastrointestinal tract which the standard 48 hour purge did not remove. The authors recommend that if mussel are to be used as environmental monitors, much longer purging periods should be employed or that analyses be completed on specific isolated tissues rather than on total soft tissue.

120.2.3R Preliminary Assessment Big River Mine Tailings Desloge, St. Francois County, Missouri, May 1988

Primarily data on Desloge for mine tailings analysis, Big River analyses, sediment analyses, and edible fish flesh for lead, cadmium, and zinc.

The highest total lead in the Big River measured was 0.020 mg/l, and the highest dissolved lead measured was 0.110 mg/l. The highest total cadmium in the Big River measured 0.002 mg/l, and the highest dissolved cadmium measured 0.004 mg/l. The highest total zinc in the Big River measured was 0.31 mg/l, and the highest dissolved zinc measured was 0.36 mg/l. Measured concentrations of metals in the Big River sediments were 2,215 μg/d dry weight for lead, 29.96 μg/g dry weight for cadmium, and 1,658.4 μg/g dry weight for zinc. Metals concentrations in edible fish flesh in the Big River ranged from 0.0 to 0.79 μg/l wet weight for lead, 0.01 to 0.03 μg/l wet weight for cadmium, and 5.12 to 16.15 μg/l wet weight for zinc. Concentrations of lead, cadmium and zinc from the Desloge tailings pile are presented in Table A-6.

TABLE A-2
METAL CONCENTRATIONS IN EDIBLE PORTIONS
OF FISH IN THE BIG RIVER

Location/Species	Lead	Cadmium	Zinc
Mineral Fork			
Smallmouth bass	0.19	0.01	13.97
Yellow bullhead	0.13	0.02	5.67
Redhorse sucker	0.08	0.01	13.42
Brown's Ford			
Smallmouth bass	0.21	0.01	4.50
Flathead catfish	0.29	0.02	12.24
Redhorse sucker	0.63	0.01	11.67
Washington State Park			
Smallmouth bass	0.27	0.01	9.49
Flathead catfish	12.00	0.34	23.00
Redhorse sucker	0.43	0.01	9.38
Mixed suckers	0.38	----	----
Desloge			
Smallmouth bass	0.05	0.01	11.73
Channel catfish	0.13	0.03	5.12
Redhorse sucker	0.57	0.03	16.15
Mixed sucker	0.79	----	---
Irondale			
Smallmouth base	0.01	<0.01	13.28
Flathead catfish	0.06	0.06	6.75
Redhorse sucker	0.02	0.01	9.32
Mixed sucker	0.07	----	---

Note:
Mean of two samples (individual fish) unless otherwise indicated. Reporting unit is μg/l wet weight.
--- indicates not reported

Source: National Fisheries Research Laboratory Report (Schmitt 1982).

TABLE A-3
METAL CONCENTRATIONS IN WATER SAMPLES COLLECTED IN THE BIG RIVER

Location/Stage	Flow (CFS)	Lead		Cadmium		Zinc	
		D	T	D	T	D	T
Mineral Fork							
Low	29.6	0.005	0.009	0.001	0.001	<0.01	<0.01
Med.	160.0	0.006	0.005	0.001	0.001	<0.01	<0.01
High	505.0	0.005	0.009	0.001	0.001	<0.01	<0.01
Brown's Ford							
Low	95.6	0.005	0.043	0.001	0.001	0.02	0.03
Med.	650.0	0.007	0.084	0.001	0.001	0.01	0.03
High	11900.0	0.026	0.440	0.001	0.001	0.05	0.17
Washington State Park							
Low	70.2	0.009	0.091	<0.001	0.001	0.01	0.04
Med.	490.0	<0.005	0.140	<0.001	<0.001	0.01	0.07
High	11395.0	0.021	0.680	<0.001	<0.004	----	0.22
Desloge							
Low	45.3	0.020	0.041	0.002	0.004	0.31	0.36
Med.	298.0	0.010	0.085	0.001	0.001	0.06	0.11
High	932.0	0.012	0.110	0.002	0.004	0.10	0.16
Irondale							
Low	7.1	0.005	0.005	0.001	0.001	<0.01	<0.01
Med.	160.0	0.005	0.005	0.001	0.001	<0.01	<0.01
High	300.0	0.005	0.005	0.001	0.001	<0.01	<0.01

Note:
CFS = *Cubic feet per second*
D = Dissolved metals
T = Total metals
Reporting unit is mg/l

Source: National Fisheries Research Laboratory Report (Schmitt 1982).

TABLE A-4
METALS CONCENTRATIONS IN SEDIMENT SAMPLES
COLLECTED IN THE BIG RIVER

Location	Lead	Cadmium	Zinc
Irondale	49.6	1.62	64.9
Desloge	2,215.0	29.96	1,658.4
Washington State Park	1,843.4	10.79	704.3
Brown's Ford	1,438.3	6.55	484.5
Mineral Fork	291.5	2.52	369.7

Note:
Adjusted total sediment metals concentrations (μg/g dry weight).

Source: National Fisheries Research Laboratory Report (Schmitt 1982).

TABLE A-5
METAL ANALYSIS OF TAILINGS

	Clay			Sand (μg/g day)		
Metal	Water	EDTA	HNO_3	Water	EDTA	HNO_3
Lead	20	2,200	2,400	26	720	850
Cadmium	ND	3.2	14	ND	5.8	25
Zinc	3.4	220	680	14	230	1,000

Note:
ND = Not detected.
Water = Rainfall through tailings.
EDTA = Ethylenediaminetetraacetic acid and represents landfill leachate through tailings.

TABLE A-6
MAXIMUM/MINIMUM CONCENTRATIONS OF LEAD, ZINC AND CADMIUM

Metal (μg/g)	Minimum	Maximum
Lead	826	6,200
Cadmium	6.8	78.6
Zinc	330	3,990

120.2.4R Continued Studies on Vagrant Lead in Fish, Mussels, and Sediments of the Big River of Southeastern Missouri

This report presents lead in fish data from 1981-1985. Several fish and shellfish were studied. Some concentrations went down in 1981 to 1985 and some went up. Sediment data in 1984 is also summarized in Table A-7. The report presents data on lead concentrations in fish filets and in shells and soft tissues of a clam (*Corbicula leana*) collected in 1985 from the Big River and its tributaries. Sediment samples were collected at each fish sampling location and analyzed by Induction Coupled Argon Plasma (ICAP) techniques for a suite of metals. The data collected in 1985 were compared with the results of previous investigations conducted in 1981, 1982 and 1984. As noted in previous studies, the 1985 investigation found that lead concentration were higher in filets of fish from sites affected by eroding tailings than control sites. Lead concentrations were consistently higher in filets from suckers (northern hog sucker and black redhorse) than in longear sunfish. Lead concentration in filets from sunfish were generally below the WHO limit of 0.3 ppm, while the lead concentrations in filets from suckers were typically above the WHO limit at sites affected by tailings. Consistent downward trends in lead concentration was noted in sunfish, but no trends were observed for suckers. No correlation was noted in sunfish, but no trends were observed for suckers. No correlation was found between rainfall or major erosion events and the concentration of lead in fish.

Clams were found at only 3 of the 11 sampling locations which precluded any detailed analysis of spatial trends. Lead concentrations in soft tissues in 1985 were higher than concentrations recorded in 1984. The highest concentrations observed in clams from the Big River in 1985 were from near Washington State Park.

Lead concentrations in sediments were highest in the Big River at Eaton Creek (sites), where values approached 3,600 ppm, and decreased downstream from this site. Elevated concentrations of calcium and magnesium in sediments were reported to be an indicator of the presence of tailings.

TABLE A-7
1984 BIG RIVER SEDIMENT DATA

Location	Metal (μg/g) 1984	Lead	Cadmium	Zinc
Big River at Bonne Terre	2,500	107	5,730	ND
Big River at Leadwood Public Access	850	7.70	480	ND

Note:
ND = No Data

120.2.6R A Study on the Possible Use of Chat and Tailings from the Old Lead Belt of Missouri for Agricultural Limestone, December 1983

This study provides sampling and analysis data for the various piles in Tables A-8 through A-15.

TABLE A-8
STATISTICAL ANALYSIS OF HEAVY METALS IN THE LEADWOOD TAILINGS PILE

Metal (μg/g)	Minimum	Maximum	Mean
Lead	597	17,000	2,444
Cadmium	9.3	1,870	267
Zinc	633	25,800	5,009

TABLE A-9
STATISTICAL ANALYSIS OF HEAVY METALS IN THE BIG RIVER DESLOGE TAILINGS PILE

Metal (μg/g)	Minimum	Maximum	Mean
Lead	826	6,200	2,077
Cadmium	6.8	78.6	26
Zinc	233	3,990	1,226

TABLE A-10
STATISTICAL ANALYSIS OF HEAVY METALS IN THE NATIONAL TAILINGS PILE, MAIN TAILINGS PILE

Metal (μg/g)	Minimum	Maximum	Mean
Lead	9,283	11,777	3,508
Cadmium	2	87	7.2
Zinc	34	5,055	457

TABLE A-11
STATISTICAL ANALYSIS OF HEAVY METALS IN THE NATIONAL TAILINGS PILE

Metal (μg/g)	Minimum	Maximum	Mean
Lead	NA	NA	2510
Cadmium	NA	NA	4.9
Zinc	NA	NA	112

Note:
NA = Not Available

TABLE A-12
STATISTICAL ANALYSIS OF HEAVY METALS IN THE NATIONAL TAILINGS PILE EAST EROSION AREA

Metal (μg/)	Minimum	Maximum	Mean
Lead	NA	NA	6,894
Cadmium	NA	NA	6.4
Zinc	NA	NA	295

Note:
NA = Not Available

TABLE A-13
STATISTICAL ANALYSIS OF HEAVY METALS IN THE ELVINS TAILINGS PILE

Metal (μg/g)	Minimum	Maximum	Mean
Lead	851	11,600	4,392
Cadmium	19.8	202	103
Zinc	108	11,900	5,482

TABLE A-14
STATISTICAL ANALYSIS OF HEAVY METALS IN THE BONNE TERRE TAILINGS PILE

Metal (μg/g)	Minimum	Maximum	Mean
Lead	1,300	7,010	3,515
Cadmium	3.0	29.5	13.9
Zinc	51.3	967	541

TABLE A-15
VARIATION OF METAL CONCENTRATION V. DEPTH OF
AUGER SAMPLE INTO TAILINGS PILE AT LEADWOOD

Metal (μg/g)	3 ft	6 ft	9 ft	12 ft	15 ft	18 ft	21 ft	24 ft
Lead	No Data							
Cadmium	250	270	180	170	160	130	120	120
Zinc	13,000	14,000	9,800	9,800	8,400	7,300	6,600	6,300

Soil samples on the Ferguson Farm indicated lead concentrations of 170 μg/g in soil, concentrations of 5.0 μg/g in grass leaves, 3.0 μg/g in grass stems, and 100 μg/g in grass roots. At the Young Farmers Field where tailings were used for agricultural limestone, lead soil concentrations ranged as high as 180 μg/g.

Background

This study compared commercially available limestone indicated lead concentrations of 9 to 1800 μg/g of lead in the limestone.

120.2.16R Abstract

This report evaluates stream conditions of the Southeast Ozark mining area from the period 1965 to 1971 based on annual surveys of benthic macroinvertebrates. Benthic macroinvertebrates were sampled from one stream in the Big River drainage - - Flat River Creek. The report notes that Flat River Creek is in good shape upstream of the tailings piles. Benthic samples had index diversity values greater than 4.0 and contained a good number of pollution sensitive mayflies and stoneflies. Downstream of the tailings piles on this stream benthic diversity was reduced drastically and there was a reduction in the number of pollution sensitive forms. The report traces the reductions to "the presence of mine tailings in the stream to such an extent that they clogged riffles and filled pools."

120.2.19R Water Quality of the Southeast Ozark Mining Area

This report evaluates stream conditions of the Southeast Ozark mining area in 1975 based on the diversity of macroinvertebrates. Benthic macroinvertebrates were sampled from one stream in the Big River drainage - - Flat River Creek. The report notes that dramatic improvements have occurred in water quality in Flat River Creek since St. Joe Minerals Corp. shut down its Federal Division in late 1972. Both invertebrate density and diversity improved since the mine closed.

120.2.20R Water Quality of the Southeast Ozark Mining Area of Missouri

Report evaluates stream conditions of the Southeast Ozark mining area in 1976 and 1978-1979 based on the diversity of macroinvertebrates. benthic macroinvertebrates were samples from one stream in the Big River drainage - - Flat River Creek. The report notes that Flat River Creek receives runoff from several inactive lead mine tailings piles and that this runoff resulted in lower diversity, lower total taxa and fewer pollution sensitive macroinvertebrates than observed at a site upstream of the runoff source.

120.2R.22 Uptake of Lead from Aquatic Sediment by Submersed Macrophytes and Crayfish

Report presents results of lead uptake laboratory investigation using two species of submerged aquatic macrophytes and crayfish. Investigation found that the two species of macrophytes (Potamogeton foliosus and Naias guadalupenis) accumulated lead in root tissue and foliage by direct exposure, but lead was not internally translocated. Plants grew rapidly and showed no obvious influence of lead sediment concentration which reached 10 μg/g lead, when plants did not survive.

Crayfish (Orconectes nais) exposed to lead contaminated sediment accumulated lead principally through absorption to the exoskeleton. Small crayfish accumulated more lead than larger specimens. Some internal assimilation of lead was indicated based on lead concentrations in green gland and hepatopancreatic tissue of exposed crayfish.

120.2.26R Further Characterization and Use of Tailings and Chat from Missouri's Old Lead Belt as Agricultural Lime

Summary of results for cadmium and lead concentrations in five tailings and chat piles in the Missouri Old Lead Belt which are summarized in Tables A-16 and A-17.

TABLE A-16
LEAD AND CADMIUM SURVEY

Location	No. of Samples	Lead (μg/g)			Cadmium (μg/g)		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum
Leadwood	98	2,444	597	17,000	267	9.3	1,870
Big River	74	2,077	826	6,200	26	6.8	79
National	93	3,508	3,172	2,844	7.2	2.5	10
Elvins	91	4,392	851	11,600	103	20	202
Bonne Terre	93	3,515	1,300	7,010	14	3.0	30

TABLE A-17
LEAD, CADMIUM, AND ZINC IN SEDIMENTS AND WATER

Metal (μg/g dry weight)	Sediment (μg/g)	Water (mg/l)
Lead	482.6	0.007
Cadmium	4.09	0.0006
Zinc	264.7	0.0668

120.2.35R Continued Evaluation of Lead in Fish and Mussels in the Big River of Southeastern, University of Missouri, June 6, 1985.

Data summary of lead in filet, bone, intestine and liver of aquatic biota.

This report presents data on lead concentrations in a variety of fish tissues, including filets, intestines, bone and liver, and the shells and soft tissues of a clam (Corbicula leana) from specimens collected in the Big River and its tributaries in the summer of 1984. The data collected in 1984 are compared with the results of previous investigations conducted in 1981, 1982 and 1983.

The filets from longear sunfish exceeded the WHO lead limit of 0.3 ppm at only two sites - Big River at Washington State Park and Flat River Creek - - and concentration of lead in filets was lower in 1984 than 1981. The filets from suckers exceeded the WHO lead limit at all sites in the Big River drainage, except for the Leadwood and Bonne Terre sampling sites.

Lead concentrations in soft mussel tissues were found to be highly variable in specimens collected from contaminated sites, dependent for purging intestinal contents.

120.2.37R *Toxic Heavy Metals in Vegetables and Forage Grasses in Missouri's Lead Belt, University of Missouri, 1973*

This report presents lead content in vegetables in control, Old Lead Belt, and New Lead Belt counties. Results for the Old Lead Belt counties are summarized in Tables A-18 and A-19.

TABLE A-18
LEAD CONCENTRATIONS IN VEGETABLE CROPS, MISSOURI'S OLD LEAD BELT
(μg/g dry)

Vegetable	Low	High	Mean	# of Samples
Lettuce Root	11.7	192.0	68.8	30
Lettuce Leaf	10.3	742.0	83.8	30
Radish Root	5.0	518.0	33.4	30
Radish Top	5.0	117.0	76.7	30
Green Bean Root	5.0	67.0	8.6	30
Green Bean Pod	5.0	10.1	5.4	30

TABLE A-19
CADMIUM CONCENTRATIONS IN VEGETABLE CROPS, MISSOURI'S OLD LEAD BELT
(μg/g dry)

Vegetable	Low	High	Mean	# of Samples
Lettuce Root	0.5	5.9	1.63	30
Lettuce Leaf	0.5	5.03	1.89	30
Radish Root	0.5	2.00	0.84	30
Radish Top	0.5	4.38	1.30	30
Green Bean Root	0.5	0.66	0.51	30
Green Bean Pod	0.5	1.10	0.70	30

In the Old Lead Belt counties of Missouri, most values for lettuce were less than 100 μg/g and most values for radish were less than 50 μg/g. Samples with high contents of lead were grown near old mines or had been grown in soils to which dolomite limestone wastes had been applied.

120.2.40R Lead in Fish from Streams in the Old and New Lead Belts of Missouri Lead Concentrations in the Tissues of Aquatic Biota.

Report presents data on lead concentrations in a variety of fish tissues, including filets, gills, scales, bones and intestines from fish collected from the Old and New Lead Belts in the spring and summer of 1982. Lead concentrations in filets of longear sunfish and various suckers were generally lower than those observed in 1980-81. Lead concentrations were generally lower in filets than other tissues samples. Lead concentrations in filets were generally higher in suckers than in Longear Sunfish. Lead concentrations were concluded to be more dependents upon seasonal and other environmental factors than upon age or size of the fish.

120.2.58R Site Assessment: Big River Mine Tailings Site, Desloge, MO, December 1991

Preliminary data for water quality from STORET. The most important contaminants sampled were lead, cadmium and zinc. Analytical results for these three contaminants for residential well proximate to Desloge were completed. Total lead was detected in five residential wells:

Thurman, Gantz, C. Smith, Matthews, and Payne at concentrations ranging from 5.9 μg/l to 32.9 μg/l. Dissolved lead was detected in only two residential wells, C. Smith (6.6 μg/ll), and Matthews (25.6 μg/l). Total lead was detected at 16 μg/l in the Payne well. Lead was detected in the two monitoring wells sampled. In well DG-5 (sample 082), lead was detected at a level of 617 μg/l (total), and 28.9 μl (dissolved). In well UG-1 (sample 081), lead was detected at 16.6 μl (total) and non-detect for dissolved. Total cadmium was only detected in monitoring well DG-5 at 7.9 μg/l. Total zinc was detected in 19 of the wells sampled at concentrations ranging from 20.1 μg/l to 457 μg/l, while dissolved zinc was detected in 20 residential wells at concentrations ranging from 20.3 to 463 μg/l. Zinc was detected in both monitoring wells up to 705 μg/l (total) and 416 μg/l (dissolved)

120.2R.61 Big River Mine Tailings/St. Joe Minerals Corp. Desloge, Missouri EPA HRS Ranking Document

EPA Hazardous Ranking System (HRS) Documentation Record Cover Sheet: Big River Mine Tailings dated August 30, 1991. HRS Ranking was documented at 84.91 with the surface water pathway evaluated at 100 and the air migration pathway evaluated at 100. Studies used for ranking included: EPA July 1990 Site Investigation, May 1988 EPA Site Investigation, and the December 1982 University of Missouri -Rolla Report. Area of tailings is stated between 593.8 and 603.8 acres (Desloge only). Background concentrations in various environmental media are presented in Table A-20.

TABLE A-20
BACKGROUND CONCENTRATIONS IN VARIOUS MEDIA

Big River Surface Water	Dissolved Lead	3.0 μg/l
Big River Surface Water	Dissolved Zinc	20 μg/l

TABLE A-20 (Continued)

Sample #	Depth	Date	Concentration (mg/kg)		
			Lead	Cadmium	Zinc
CSXCR012	0-6"	7/23/90	65	1.3	35
CSXCR017	0-6"	7/26/90	64	1.2	66
CSXCR020	0-6"	7/26/90	76	1.2	67
CSCCR024	0-6"	7/27/90	99	1.2	98
CSXCR025	0-3"	7/28/90	130	1.6	53

Contaminated soils concentrations from the study are presented in Table A-21.

TABLE A-21
CONTAMINATED SOILS (DESLOGE)

Sample #	Depth	Date	Concentration (mg/kg)		
			Lead	Cadmium	Zinc
CSXCR002	0-6"	7/24/90	1,000	21	950
CSXCR003	0-6"	7/24/90	1,100	14	570
CSXCR004	0-6"	7/24/90	1,400	20	840
CSXCR005	0-6"	7/24/90	930	8.4	370
CSXCR006	0-6"	7/24/90	1,500	19	870
CSXCR007	0-6"	7/24/90	1,700	28	1,200
CSXCR008	0-6"	7/24/90	1,600	30	1,300
CSXCR009	0-6"	7/24/90	1,300	13	610
CSXCR010	0-6"	7/24/90	13,000	79	4,300
CSXCR011	0-6"	7/24/90	970	24	1,200

Contaminated offsite soils information from the study are presented in Table A-22.

TABLE A-22
OFF SITE METAL SAMPLE CONCENTRATIONS AT DESLOGE

Sample	Depth	Date	Concentration (mg/kg)		
			Lead	Cadmium	Zinc
CSXCR022	0-6"	7/26/90	650	270	13,000
CSXCR026	0-6"	7/27/90	1,300	25	1,100
CSXCR030	0-6"	7/27/90	2,200	7.9	430

The nearest residence to the tailings pile is 100 feet south of the site on the southwest edge. This is sample no. CSXCR022, the Kyle residence. The day care center playground (sample no. CSXCR026) was collected about 1500 feet south of the pile. Sample no. CSXCR030 was collected about 1,000 feet south of the pile. This sampling indicates that the most significant areas of influence from the Big River mine tailings pile to be east and southeast. Air monitoring was also referenced and EPA designated benchmark for zinc in soils of 12,000 mg/kg is stated. The designated benchmark for cadmium is 290 mg/kg. The designated lead benchmark 400 mg/kg was extracted from July 1994 EPA lead guidance.

In this report an Area A is defined as the tailings area and equals 503.8 acres, and Area B is the contaminated surface soils area and equals 46.5 acres. A soil sample on the Wood's property which is a commercial farm was taken. The farm raises cattle and alfalfa. Soil samples for lead were not significantly above background.

Air Monitoring Data

To assess background air concentrations of tailings dust on-site and off-site a series of high volume air monitoring stations were deployed. These high volume air samplers collect particulate matter. It was not stated if these monitors measure only PM10 or the inhalable size fraction of collected particulate. Background air monitoring was sensitive to the wind direction and the monitors were primarily located one-mile west and southwest of the southern edge of the Big River Tailings Pile. Table A-23 presents background air samples.

TABLE A-23
BACKGROUND AIR SAMPLES

Sample #	Height	Date	Concentration ($\mu g/m^3$)		
			Lead	Cadmium	Zinc
CSXCR407	6'	7/23/90	0.008	0.001	0.015
CSXCR422	6'	7/24/90	0.020	0.000	0.020
CSXCR414	6'	7/24/90	0.027	0.001	0.020
CSXCR430	6'	7/26/90	0.036	0.001	0.024
CSXCR438	6'	7/27/90	0.022	0.000	0.024
CSXCR445	6'	7/28/90	0.059	0.001	0.064

Table A-24 presents contaminated air samples.

TABLE A-24
CONTAMINATED AIR SAMPLES

Sample #	Height	Date	Concentration ($\mu g/m^3$)		
			Lead	Cadmium	Zinc
CSXCR404	6'	7/24/90	0.569	0.006	0.261
CSXCR412	6'	7/27/90	0.082	0.008	.0380
CSXCR417	6'	7/25/90	ND	0.001	ND
CSXCR418	6'	7/25/90	ND	0.001	ND
CSXCR419	6'	7/26/90	ND	0.003	ND
CSXCR428	6'	7/27/90	1088	0.009	0.473
CSXCR433	6'	7/27/90	ND	0.001	ND
CSXCR435	6'	7/27/90	0.294	0.004	0.171
CXSCR436	6'	7/27/90	0.429	0.004	0.232
CSXCR444	6'	7/28/95	0.190	ND	ND

120.2.62.and 63R Site Assessment: Big River Mine Tailings, Desloge, Missouri, Addendum Report

On August 19-25, 1992, the EPA's Technical Assistance Team (TAT) conducted a site assessment of the Big River Mine Tailings site in Desloge, Missouri. The TAT utilized two specific XRF models to screen on-site tailings and off-site soils for lead. A total of 405 samples were screened and 56 samples were submitted to the EPA Region VII Laboratory for confirmation analyses. Also, TAT collected 35 water samples from residential drinking wells and a spring near the site.

Residences were selected for water sampling based on previous EPA investigations. The Goff residence and the day care center were not sampled since they are on a City water supply system and they do not use private wells. No private wells were found in the Desloge City limits. Twelve residential wells were sampled. All water samples were sent to EPA's Region VII Laboratory for lead, cadmium, zinc, and arsenic analyses. Arsenic was not detected in any sample except for sample RW1CR-096 (7.7 μg/l). Zinc was detected in all samples at low levels.

Of the water samples analyzed, only a few samples showed concentrations above or approaching Maximum Contaminant Levels (MCLs). The tap water sample collected from the Matthews residence showed 12 μg/l of cadmium and 21 μg/l of lead.

Tap water collected from the Kennedy residence showed 12 μg/l of lead. This elevated concentration could result from plumbing since the water sample collected from the spigot nearest the well only showed a lead concentration of 4 μg/l. The tap water sample collected from the Schibblehut residence showed a cadmium concentration of 6 μg/l while the outdoor spigot showed a cadmium concentration of 1 μg/l.

Tap water and outdoor spigot samples collected from the Payne residence showed elevated lead concentrations of 13 and 16 μg/l, respectively. The water samples collected from the landfill office well and spring showed lead concentrations of 16 and 28 μg/l, respectively. Tables A-25 and A-26 summarize the information provided by this reference.

TABLE A-25
SUMMARY OF FIELD SCREENING XRF RESULTS
BIG RIVER MINE TAILINGS
DESLOGE, MISSOURI
T07-9210-004/EMO0616SFA

FIELD I.D.	XRF VALUE LEAD		FIELD I.D.	XRF VALUE LEAD
A1-001	1710		A1-034	1360
A1-002	1320		A1-035	1270
A1-003	940		A1-036	1960
A1-004	1270		A1-037	1040
A1-005	1020		A1-038	1240
A1-006	970		A1-039	1380
A1-007	1060		A1-040	1360
A1-008	1150		A1-041	1030
A1-009	820		A1-042	930
A1-010	1060		A1-043	1080
A1-011	790		A1-044	980
A1-012	680		A1-045	1090
A1-013	1170		A1-046	1360
A1-014	1090		A1-047	1070
A1-015	870		A1-048	1410
A1-016	900		A1-049	1560
A1-017	1470		A1-050	1190
A1-018	1050		A1-051	810
A1-019	1710		A1-052	1020
A1-020	1550		A1-053	880
A1-021	1320		A1-054	117
A1-022	1500		A1-055	980
A1-023	670		A1-056	1090
A1-024	1220		A1-057	940
A1-025	1350		A1-058	1320
A1-026	1220		A1-059	990
A1-027	1000		A1-060	1100
A1-028	1060		A1-061	1200
A1-029	1140		A1-062	1550
A1-030	1210		A1-063	1140
A1-031	1030		A1-064	1680
A1-032	1200		A1-065	1170
A1-033	1330		A1-066	1410

TABLE A-25 (Continued)
SUMMARY OF FIELD SCREENING XRF RESULTS
BIG RIVER MINE TAILINGS
DESLOGE, MISSOURI
T07-9210-004/EMO0616SFA

FIELD I.D.	XRF VALUE LEAD		FIELD I.D.	XRF VALUE LEAD
A1-067	1450		A1-100	1170
A1-068	1060		A1-101	1190
A1-069	1070		A1-102	1430
A1-070	1010		A1-103	1230
A1-071	1090		A1-104	1290
A1-072	890		A1-105	1280
A1-073	1090		A1-106	1020
A1-074	970		A1-107	1340
A1-075	1070		A1-108	1010
A1-076	1170		A1-109	1250
A1-077	1260		A1-110	1130
A1-078	1430		A2-01	2540
A1-079	1350		A2-02	2200
A1-080	1320		A2-03	1560
A1-081	1600		A2-04	1500
A1-082	1120		A2-05	1210
A1-083	1420		A2-06	1650
A1-084	1000		A2-07	2820
A1-085	1640		A2-08	2620
A1-086	1330		A2-09	1950
A1-087	1010		A2-10	1050
A1-088	390		A3-111	280
A1-089	1180		A3-112	540
A1-090	980		A3-113	260
A1-091	1380		A3-114	330
A1-092	980		A3-115	230
A1-093	1310		A3-116	730
A1-094	1530		A3-117	520
A1-095	930		A3-118	830
A1-096	1150		A3-119	150
A1-097	1250		A3-120	110
A1-098	1350		A3-121	70
A1-099	1260		A3-122	1600

TABLE A-25 (Continued)
SUMMARY OF FIELD SCREENING XRF RESULTS
BIG RIVER MINE TAILINGS
DESLOGE, MISSOURI
T07-9210-004/EMO0616SFA

FIELD I.D.	XRF VALUE LEAD		FIELD I.D.	XRF VALUE LEAD
A3-123	170		A3-156	150
A3-124	30		A3-157	170
A3-125	860		A3-158	430
A3-126	230		A3-159	150
A3-127	230		A3-160	0
A3-128	890		L1-01	780
A3-129	600		L1-01-A	0
A3-130	150		L1-01-B	740
A3-131	530		L1-02	40
A3-132	820		L1-02-A	0
A3-133	790		L1-02-B	530
A3-134	0		L1-03	170
A3-135	1270		L1-03-1	310
A3-136	610		L1-03-B	670
A3-137	110		L1-04	30
A3-138	70		L1-04-A	60
A3-139	0		L1-04-B	140
A3-140	0		L1-05	110
A3-141	330		L1-05-A	0
A3-142	0		L1-05-B	0
A3-143	270		L1-06	0
A3-144	230		L1-06-A	0
A3-145	290		L1-06-B	0
A3-146	230		L1-07	110
A3-147	840		L1-07-A	0
A3-148	510		L1-07-B	400
A3-149	0		L1-08	50
A3-150	240		L1-08-A	30
A3-151	240		L1-08-B	90
A3-152	850		L1-09	10
A3-153	2250		L1-09-A	310
A3-154	2440		L1-09-B	0
A3-155	0		L2-01	320

TABLE A-25 (Continued)
SUMMARY OF FIELD SCREENING XRF RESULTS
BIG RIVER MINE TAILINGS
DESLOGE, MISSOURI
T07-9210-004/EMO0616SFA

FIELD I.D.	XRF VALUE LEAD		FIELD I.D.	XRF VALUE LEAD
L2-01 (TAILINGS MODEL)	510		L3-02-A	100
L2-01-A	1500		L3-03	420
L2-01-B	730		L3-03-A	30
L2-02	2130		L3-04	0
L2-02-A	510		L3-04-A	0
L2-02-B	750		L3-05	0
L2-03	0		L3-05-A	0
L2-03-A	830		L3-06	0
L2-03-B	0		L3-06-A	0
L2-04	0		L3-07	0
L2-04-A	130		L3-07-A	0
L2-04-B	0		L3-08	0
L2-05	1160		L3-08-A	0
L2-05-A	0		L3-09	0
L2-05-B	1490		L3-09-A	10
L2-06	2660		L3-10 (50'from Big River)	2440
L2-06-A	2870		L3-10-A (50'from Big River)	3110
L2-06-B	2610		L4-01 (tailings model)	1090
L2-07	1680		L4-02 (near river)	2640
L2-07-A	2010		LF-03	390
L2-07-B	590		L4-04	0
L2-08	1700		L4-05	0
L2-08-A	570		L4-06	0
L2-08-B	170		L4-07	0
L2-09	0		L4-08	0
L2-09-A	1420		L4-09	70
L2-09-B	140		L4-10	50
L2-10	300		L5-01	10
L2-10-A	110		L5-02	0
L2-10-B	0		L5-03	0
L3-01	1850		L5-04	0
L3-01-A	220		L5-05	0
L3-02	930		L5-06	0

TABLE A-25 (Continued)
SUMMARY OF FIELD SCREENING XRF RESULTS
BIG RIVER MINE TAILINGS
DESLOGE, MISSOURI
T07-9210-004/EMO0616SFA

FIELD I.D.	XRF VALUE LEAD		FIELD I.D.	XRF VALUE LEAD
L5-07	660		L8-10	10
L5-08	30		G-1 0'-2'	1090
L5-09	0		G-1 2'4'	1070
L5-10	0		G-14'-6'	1070
L6-01 (near river)	2480		G-1 6'-8'	1040
L6-02	0		G-1 8'-10'	1000
L6-03	0		G-2 0-2'	1300
L6-04	0		G-2 2'-4'	1300
L6-05	0		G-2 4'-6'	730
L6-06	280		G2 6'-8'	640
L6-07	270		G-2 8'-10'	1200
L6-08	370		G-3 0-2'	1260
L6-09	230		G-3 2'-4'	1280
L6-10	120		G-3 4'-6'	1270
L7-01 (near river)	3040 *		G3 6'-8'	1270
L7-02	0		G-3 8'-10'	1310
L7-03	0		G-4 0-2'	970
L7-04	0		G-4 2'-4'	1030
L7-05	60		G-4 4'6'	1160
L7-06	0		G-4 6'-8'	1180
L7-07	0		G-4 8'-10'	1060
L7-08	0		G-5 0-2'	2500
L7-09	440		G-5 2'-4'	2370
L7-10 (near river)	2680		G-5 4'-6'	2290
L8-01 (near river)	3110		G-5 6'-8'	2570
L8-02	0		G-5 8'-10'	4350*
L8-03	0		A-4 Chestnut & 8th St.	540*
L8-04 (near river)	1660		A-4 Mathews Yard	340
L8-05	0		A-4 McMullin Yard	2230
L8-06	0		A-4 Forbes Yard	380
L8-07 (near railroad)	2220		A-4 Akins Yard	440
L8-08	0		A-4 Eaton Yard	270
L8-09	0		A-4 Waters Yard	150

TABLE A-26
SUMMARY OF FIELD SCREENING XRF RESULTS
BIG RIVER MINE TAILINGS SITE
DESLOGE, MISSOURI
T07-9210-004/EMO0616SFA

FIELD I.D.	XRF VALUE LEAD
A-4 Woems Yard	2700
A-4 Kennedy Yard	0
A-4 Gantz Yard	850
A-4 Schibblehut Yard	560
A-4 Payne Yard	50
A-4 Rhodes Yard	100
A-4 Goff Yard	710
A-4 Goff North Lot	2700
A-4 Kiddie Castle (Day Care Center)	280

Note:
* Indicates an average of multiple XRF reading.

120.2.66R & 67R Final Report - Listing Site Inspection Big River Mine Tailings Volume I and Shaft Data

MDNR collected air quality data near Flat River, Missouri approximately two miles southeast of the site. MDNR used one Hi-vol air sampler located approximately 2,000 feet north of St. Joe tailings pile (Federal pile). Data were collected for a three-year period from 1981 to 1983. Monitor filters taken during initial sampling period of January through August were analyzed for lead. These data are total suspended particulate and not PM10, the respirable fraction. No additional filters in the three year period were analyzed for lead. The TSP annual geometric mean for 1981 was 50.55 $\mu g/m^3$; 1982 was 35.47 $\mu g/m^3$, and 1983 was 47.43 $\mu g/m^3$. The national Ambient Air Quality Standard for TSP is 75 $\mu g/m^3$. The results of the lead analyses for the first three quarters of 1981 were January to March 0.14 $\mu g/m^3$, April to June 1.09 $\mu g/m^3$, and July to August 0.17 $\mu g/m^3$. The NAAQS for lead in a calendar quarter is 1.5 $\mu g/m^3$. These results are all within the standards for air quality.

Final report. listing Site Inspection: Big River Mine Tailings, Desloge, Missouri. Submitted to EPA Region VII by the Field Investigation Team (FIT). October 30, 1991. Provides metals concentrations in the Big River Water and Sediment. Recaps a study by National Marine

Fisheries Laboratory (NMFL) in 1982 where water was sampled for lead cadmium and zinc at low, medium and high water flows. Additionally, metals were sampled for NMFL in 1982 for lead cadmium and zinc in sediments of the Big River.

Metals in aquatic biota were sampled by NFRL in 1982 for lead cadmium and zinc in small mouth bass, yellow bullhead, and red horse sucker. Samples were taken at Mineral Fork, Brown's Ford Washington State Park, Desloge, and Irondale. Tables A-27 through A-33 summarize the information provided in the LSI.

TABLE A-27
POPULATION SURROUNDING THE SITE IN FOUR-MILE RADIUS

Distance from Site (miles)	Population
0 - 1/4	52
1/4 - 1/2	235
1/2 - 1	2,399
1 - 2	11,443
2 - 3	6,469
3 - 4	238

Sources: USGS 1982, St. Francois 1983, EPA 1989, U.S. Census 1991

TABLE A-28
MUNICIPAL GROUND WATER USAGE IN FOUR-MILE RADIUS OF THE
BIG RIVER MINE TAILINGS SITE, DESLOGE, MISSOURI

Water District	Municipalities Served	Population Served	Well Identification	Total Depth (feet)	Formation	Distance From Site
Flat River	Flat River Desloge Elvins Leadington Ester River Mines	4,443 3,581 1,548 238 1,038 414	#1 Sealed mine shaft #2	432 410	Bonne Terre Lamotte	~ 2 miles 3000 ft.
Leadwood	Leadwood Gumbo	1,371 ~ 90	#1 #2	700 790	Unknown Unknown	~2.5 miles ~2.5 miles
Bonne Terre	Bonne Terre	3,797	#1 #2	746 720	Lamotte Lamotte	~1.5 miles ~1.5 miles
Terre Dulac	Terre Dulac	~2,000	#1 #2 #3	1,030.5	Unknown Unknown Unknown	~3.5 miles ~3.5 miles ~3.5 miles

Sources: Tille 1988; Hedgeworth 1988; Warren 1988; Johnson 1987a; Degonia 1988.

TABLE A-29
SELECTED METALS IN SOIL AND TAILINGS SAMPLES
BIG RIVER MINE TAILINGS SITE
DESLOGE, MISSOURI
E & E/FIT: JULY 1990
SAMPLE SERIES CSXCR

Sample (mg/kg)	Arsenic	Cadmium	Cobalt	Lead	Nickel	Zinc
* 001	6.3	1.20	14	130 J	9.4 U	65
* 002	14	21	13	1000 J	18 J	950
* 003	7.7	14	11	1100 J	15 J	570
* 004	8.1	20	11 U	1400 J	8.5 U	840
* 005	8.6	8.4	14	930 J	15 J	370
* 006	9.6	19	27	1500 J	20 J	870
* 007	9.4	28	15	1700 J	12 J	1200
* 008	2.1 U	30	13	1600 J	14 J	1300
* 009	9.7	13	12	1300 J	16 J	610
* 010	14	79	42	13000 J	37 J	4300
* 011	6.5	24	10 U	970 J	9.0 J	1200
b-012	9.3	1.3 U	16	65 J	10 U	35
013	6.9	1.2 U	15	450 J	9.6 U	42
014	6.2	1.3 U	16	85 J	17 J	57
015	8.2	3.2	16	370 J	11 J	180
016	13	6.0	13 U	940 J	10 U	490
b-017	9.5	1.2 U	14	64 J	9.5 U	66
b-018	7.2	4.8	16	1500 J	12 J	370
b-019	6.8	5.3	18	1600 J	12 J	390
b-020	6.2	1.2 U	12 U	76 J	9.4 U	67
* 021	2.3 U	16	19	1500	20	760 J
022	2.2 U	270	16	650	8.8 U	13000 J
023	2.1 U	2.1	12	190	15	140 J
024	2.3 U	1.2 U	12 U	99	9.2 U	98 J
025	3.1 U	1.6	18	130	12 U	53 J
026	2.3 U	25	13	1300	9.6	1100 J
* 027	2.4 U	11	38	1500	36	630 J
* 028	2.1 U	10	10 U	1600	9.5	510 J
* 029	7.0 J	11	11 U	910	9.1 U	510 J
030	7.6 J	7.9	23	2200	21	430 J

Note:
b = Background Sample
* = Tailings Sample
J = Data reported, but not valid by approved QA/QC procedures
U = Less than measurement detection limit, the associated number is the detection limit.

The four subsurface tailings samples (009, 027, 028 and 029) were collected at 0 to 6 inches, 5 to 6 feet, 10 to 11 feet, and 15 to 16 feet, respectively. Concentrations of cobalt, lead, and nickel increased significantly from the 0 to 6 inches to the 5- to 6-foot interval. The following concentrations were reported:

TABLE A-30

Sample #	Depth (feet)	Cobalt (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)
002	0-.5	12	1,300 J	16 J
027	5-6	38	2,500	36
028	10-11	10 U	1,600	9.5
029	15-16	11 U	910	9 U

Note:
J = Data reported but not valid by approved QA/QC procedures.
U = Less than measurement detection limit. The number shown is the detection limit.

TABLE A-31
SELECTED METALS IN SEDIMENT SAMPLES
BIG RIVER MINE TAILINGS SITE
DESLOGE, MISSOURI
E & E/FIT: JULY 1990
SAMPLE SERIES CSXCR

Sample (mg/kg)	Arsenic	Cadmium	Cobalt	Lead	Nickel	Zinc
* 100	4.4 J	1.1 U	11 U	1.1	9.0 U	21 J
* 101	5.5 J	1.1 U	11 U	1.4	9.1 U	53 J
102	2.5 U	140	12 U	10,000	9.8 U	6,500 J
103	30 J	46	13 U	720	10 U	1,900 J
104	2.2 U	130	11 U	5,500	8.9 U	6,600 J
105	6.2 J	21	11 U	1,700	10	840 J
106	8.3 J	42	12 U	1,600	9.3 U	2,200 J
107	9.0 J	88	12 U	3,600	12	4,500 J
108	2.2 U	59	11 U	1,300	9.6	2,600 J
109	6.4 J	24	12 U	1,300	13	1,100 J
110	5.5	32	52	540	59	1,900
111	6.7	6.3	10 U	350	13	400
112	11	63	13 U	3,100	12	3,300
112 D	6.4	120	12 U	3,400	9.8 U	6,700
113	18	16	12 U	2,500	12	810
114	7.9	28	12 U	3,800	11	1,800
115	21	18	16	3,500	18	970
116	7.1	14	12	1,200	13	1,000
117	11	37	44	8,700	58	1,500
* 118	2.2 U	1.0 U	10 U	4.4	5.8	7.7 U
119	5.5 J	6.1	11 U	610	13	370
120	4.5 U	3.7 U	1.1 U	680	8.6 U	290

Note:
* = Background Sample
J = Data reported, but not valid by approved QC procedures
U = Less than measurement detection limit, the associated number is the detection limit.

TABLE A-32
SELECTED METALS IN SURFACE WATER SAMPLES
BIG RIVER MINE TAILINGS SITE
DESLOGE, MISSOURI
E & E/FIT: JULY 1990
SAMPLE SERIES CSXCR

Sample	Lead		Zinc	
(μg/l)	Total	Dissolved	Total	Dissolved
* 200	3.0 U	3.0 U	20 U	20 U
* 201	3.0 U	3.0 U	74	20 U
202	61	23	1,300	1,200
203	15	3.0 U	44	20 U
204	37	3.3 U	81	44
205	29	3.0 U	74	41
206	32	3.0 U	84	56
207	34	3.9 U	100	68
208	33	4.0	98	68
209	31	4.5	98	86
210	6.0	3.0 U	42	20 U
211	26	3.0 U	62	34 U
212	29	4.4	120	100
212 D	28	4.8	130 U	99
213	30	5.4	130	110
214	27	5.7	150	130
215	32	16	120	130
216	49	9.5	130	100
217	22	11	34 U	31 U
* 218	3.0 U	3.0 U	20 U	20 U
219	26 J	8.2 J	91	62
220	49 J	11 J	70	39

Note:
See referenced report for sample locations.
* = Background Sample
J = Data reported, but not valid by approved QA/QC procedures
U = Less than measurement detection limit, the associated number is the detection limit.

TABLE A-33
SUMMARY OF SAMPLES COLLECTED

Media/ Strata	No. of Field Screening Samples	No. of Lab Samples	No. of Duplicate Samples	No. of Field Spikes	No. of Field Blank	Total Lab Samples
SURFACE SOIL						
Area 1	110	11				11
Area 2	10	1				1
Area 3	50	5				5
Area 4	80	8	8 *	a		16
Residence & Day Care	200	20 (max)				20
SUBSURFACE SOIL						
	25	5				5
GROUND WATER						
		28	8 *	9	1	37
TOTAL	475	78	16	a	1	95

Note:
* = Duplicate samples collected in accordance with OSWER Directive 93604-10, and will be used to calculate the precision in accordance with OSWER Directive 9360.4-01.

a = Field spike samples and the determination of field accuracy is pending the spiking solution. If the spiking solution is provided by the EPA Lab, eight samples will be spiked on site for each sample media. Analytical results of the spiked samples will be used to calculate the accuracy in accordance with OSWER Directive 9360.4-01.

120.2.3R EPA FIT investigation in 1988.

The 1988 E&E FIT report prepared for EPA compiles previous studies and history from previous investigations. Well log information for the on-site landfill is provided. An EPA form 2070-12 is completed.

120.2.59R EPA Region VII, Kansas City. Engineering Evaluation/Cost Analysis for the Big River Mine Tailings Site, Desloge,Missouri. A Non-Time Critical Removal Action for Dust Control, Bank Stabilization, and Storm Water Runoff Control. December 1993.

This document provides background on the Big River Mine Tailings site. Identification of removal action objectives, identification and screening of removal actions, preliminary identification of ARARs and Analysis of proposed removal action alternatives. Document calculates the waste volume of BRMTS as 48 million cubic yards and states that the primary contaminant is lead.

120.2.78R Preliminary Public Health Assessment for Big River Mine Tailings/St. Joe Minerals, Desloge, Missouri (MDOH/ATSDR, January, 1994).

A review of previous studies with a summary of soil data samples taken from residential yards stated that:

- cadmium ranged from 1.3 to 14.2 ppm
- lead ranged from 184 to 3,200 ppm
- zinc ranged from 94.9 to 918 ppm
- arsenic was non detectable at 20 ppm.

ATSDR uses comparison values to determine if a specific chemical needs further evaluation. Reference levels and their source for the listed chemical are:

- cadmium, 1 ppm, pica child EMEG
- lead, no value is presently available for lead, as it is undergoing evaluation
- zinc, 600 ppm, pica child RMEG
- arsenic, 0.4 ppm, CREG.

Water for the cities adjacent to Big River Mine Tailings/St. Joe Minerals site is supplied by the Flat River Water District. The water district included Flat River, Elvins, Desloge, Leadington, Ester, and Rivermines. The water district obtains its water from tow main sources including a well in Desloge, and a flooded mine shaft in Rivermine. Samples from these water sources indicated Desloge with a lead concentration of 5 ppb, and the flooded mine shaft with 49 ppb. At the time of sampling (1985/1986) the EPA MCL was 50 ppb. EPA has since replaced the MCL with a public drinking water action level of 15 ppb (MDOH, 1994).

Results of an EPA FIT investigation in 1991 indicated no volatiles, semi-volatiles or pesticides in private drinking water wells. Out of 44 wells, five had levels of dissolved lead in the range of 5.9 to 32.9 ppb. Dissolved lead was only found in two residential wells at 6.6 and 25.6 ppb. Total and dissolved cadmium was not detected in any of the private wells. Total zinc was detected in 20 private wells with levels ranging from 20.1 to 463 ppb. Other metals detected in private wells were at levels below MCLs (MDOH,1994).

120.2R.57 Suggested Removal Action Alternative for Consideration in Controlling Wind Erosion and Bank Stabilization - Big River Mine Tailing Site - Desloge, Missouri, March 24, 1993

Plans for Desloge includes grading, drainage basins chemical stabilizers, revegetation and other drainage improvements. A biodegradable erosion control fabric will also be used.

120.2R.43 PTI, Assessing the Validity of Lead Bioavailability Estimates from Animal Studies, March 15, 1993

Paper reports that EPA usually uses the IEUBK Model to assess blood lead levels from lead in soils. However, blood testing at mining communities has indicated blood lead levels "much lower" than those predicted by the model. Paper reviews various studies done around the nation on lead bioavailability to children.

120.2R.38 An Evaluation of the Acute Toxicity of Lead, Zinc, and Cadmium in Missouri Ozark Groundwater Nord Gale, University of Missouri - Rolla

Study conducted testing of lead, zinc and cadmium on fatlead minnow (*pimephales promelas*) and *Daphnia* magna. Metal concentrations were synthetic and not actual mining wastes. Results were inconclusive and "observed mortality did not consistently correlate well with metal concentrations determined on various fractions.

120.2.76R Bioavailability and Toxicity of Metals Leached from Lead Mine Tailing to Aquatic Invertebrates, J. Resser and C. Rabeni, Missouri Cooperative Fish and Wildlife Research Unit, May 1987.

The paper uses experimental methods indicates that using vegetation and organic cover, on mine tailings piles influences the bioavailability of metals.

Report presents results of a laboratory investigation of the bioavailability and toxicity of lead and cadmium leached from tailings from the Desloge tailings pile on three species of aquatic invertebrates, a crayfish (*Chironomus riparius*), a mayfly (*Hexagenia limbata*) and a midge (*Chironomus riparius*). Six test plots were leached with rainwater and the three species of aquatic invertebrates were exposed to the collected leachate. Five of these plots were filled with tailings and the sixth plot was filled with dolomite and used as a control. Two of the tailings plots were vegetated and two others were treated with organic mulches. The leachate exposure studies were conducted in 1983, one year after the plots were established.

Metal bioaccumulation by invertebrates during the leachate exposures varied widely among cover treatments, with the organic mulch (leaf and dried sewage sludge) exhibiting the greatest increases in bioaccumulation. Metal bioaccumulation was positively associated with dissolved metal concentration in the leachates. It was postulated that the soluble metal complexes were formed with the humic acids from the treatments. Toxic effects were observed in crayfish (survival) and midges (survival and growth) exposed to the tailings leachates.

The authors noted that their study suggests that the addition of vegetation and organic materials to tailings, as could occur as part reclamation activities, can be associated with increased mobilization of biologically available metals in leachates.

120.2R.25 Bioavailability of Pb and Zn from Mine Tailings as Indicated By Erythrocyte θ-Aminoleuulnic Acid Dehydratase (ALA-D) Activity in Suckers (Pisces: Catostomidae), C. Schmitt, F. Dwyer and S. Finger, U.S. Fish and Wildlife Service, 1984

Report presents data on lead and zinc concentrations in fish filets and blood erythrocyte enzyme activity in suckers collected from the Big River and its tributaries in April 1981. Lead concentrations in the filets of the suckers (black redhorse, golden red horse and northern hog sucker) exceeded the WHO limit of 0.3 μg/g in most specimens collected from areas affected by tailings, while the highest concentration at the control site was only 0.13 ppm. The results of this study confirmed the earlier findings of the Missouri Department of Conservation.

The concentration of lead and zinc in blood showed the same trends as the filets results, with the highest concentrations observed in stream segments affected by tailings. Differences in blood zinc concentrations between affected sites were less pronounced than those for blood lead. Erythrocyte ALA-D activity was found to be depressed at sites downstream of sources of mine tailings and significant relations were reported between blood zinc and lead concentrations and enzyme activity. ALA-D activity was negatively correlated with blood and filets lead concentrations. The report concludes that ALA-D activity can be used as an indication that an organism has been recently exposed to lead, but that no symptoms of chronic exposure to lead, such as a black tail, lordosoliosis or behavioral abnormalities, were observed in the several hundred fish handled from the Big River.

120.2R.39 B. Wixon, L. Elliott and N. Gale, University of Missouri, Influence of Tailings from the Old Lead Belt of Missouri on Sediments of the Big River

Report presents data on lead, zinc, cadmium and copper concentrations in water and sediment samples from the Big River and its tributaries. Concentrations of lead in river waters were generally well below 0.05 ppm, except where affected by sewage effluent from the Desloge-Flat River city sewage treatment plant.

The highest concentrations of lead in sediment were observed in the Big River downstream of the confluence with Eaton Creek. The maximum lead concentration recorded at this location (173,000 ppm) was noted to be larger than the maximum concentration in tailings (6300 ppm) and Eaton Creek sediments (3900 ppm), suggesting another source of lead to the sediments. The concentration of lead in the sediments below the Desloge - Big River tailings pile ranged from 1000-2200 ppm, reflecting the concentrations found in the tailings pile (1200-3400 ppm). Lead concentrations were found to be considerable higher in the sediments taken from Flat River Creek than those from the Desloge Bonne Terre area. The report concludes that "the observed pattern of elevated lead levels suggests that the problem exists throughout the Leadwood-Desloge-Flat River-Bonne Terre region."

120.2.27R K. Palmer et al., Ministry of the Environment, Ontario Lead Contamination of Sycamore and Soil from Lead Mining and Smelting Operations in Eastern Missouri, March 1980

Paper reports lead concentrations in washed foliage and soils in Eastern Missouri at six locations. The Desloge location is one of the six and Table A-33 below presents the data for this location.

TABLE A-33
AVERAGE LEAD CONTENT IN SYCAMORE LEAF, TWIG, AND SOILS
AT TWO DISTANCES FROM THE SITE: 0.8 and 8.0 km

km								
	Leaf Tissue		Twig Tissue		Soil (A)		Soil (T)	
Site	≤0.8*	8.0*	≤0.8*	8.0*	≤0.8*	8.0*	≤0.8	8.0 km*
Lead Concentration (ppm)								
Desloge	40.3	6.5	18.5	3.3	841.1	77.8	1,816.7	426.4

Note:
* Distance in km from the Desloge site.

120.2R.28 Chemistry and Plant Ecology of Zinc-rich wastes dominated by Blue-Green Algae, B. Whilton, N. Gale and B. Wixon, 1981

Report presents results of an investigation of the water chemistry and vegetation in the zinc rich seepage from the Elvins tailings pile and the changes in these parameters as the seepage flows towards Flat River Creek. The two most widespread plants in the area investigated were a blue-green alga, <u>Plectonema gracillimum</u> and a moss, <u>Dicranilla</u> sp. Marked changes in chemistry and vegetation were noted as the seepage flowed from its source to a site 15 meters downstream. The report concludes that chemical chances in the seepage water, including reductions in aqueous zinc concentrations, maybe partly the result of the vegetation.

120.2R.9 Elemental Composition of Selected Native Plants and Associated Soils From Major Vegetation - Type Areas in Missouri, J. Erdman and H. Shacklette, U. S. Geological Survey, 1976

Provides the six principal vegetation types of native Missouri plants and documents background metal concentrations in vegetation prior to the 1977 event at Desloge. Conclusion was that chemical composition in the ash of selected vegetation and native plants was found to only weakly reflect, the chemical composition of associated soils.

120.2.10R The Dynamics of Metals from Past and Present Mining Activities in the Big and Black River Watershed, Southeastern, Missouri, 1982.

Report presents the results of an investigation conducted by the U.S. Fish and Wildlife Service for the U.S. Army Corps of Engineers, St. Louis District, as part of the study of a proposed reservoir, Pine Ford Lake, on the Big River. The investigation was designed to evaluate the magnitude of the trace metals problems in the Big River Watershed under present conditions, and to provide preliminary data with which to assess the impacts of the proposed reservoir on trace metal dynamics.

The report provides a great deal of basic information on the transport, dynamics, fate and to a lessor extent, biological effects of potentially toxic metals in the Big River drainage. The investigation included one of the most comprehensive biological investigation conducted on the Big River, included trace metals analyses of tissue samples from several species of fish, pocketbook mussels, crayfish, water willow and attached algae; and blood enzyme (ALA-D) activity determinations and blood lead levels on longear sunfish, redhorse suckers and northern hog suckers. Unlike many other studies, biological samples collected from this study were analyzed for a suite of metals including lead, cadmium, copper, zinc, iron, magnesium and barium. A key aspect of this study is that it provides whole-body metals analyses that can be used for ecological risk assessments.

The biological portion of the investigation found elevated concentrations of lead, cadmium and zinc from every biological form examined - - algae, rooted plants, crayfish, mussels and fish - - in the Big River downstream of the tailing piles located in this drainage. Highest concentrations of metals in biological tissues were typically found in the vicinity of Desloge, with decreasing concentrations downstream. The investigation documented that the concentration of lead in the edible portions of some fish from the affected reaches of the Big River exceed recommended levels for human consumption, which corroborated the earlier findings of the Missouri Department of Conservation.

120.2R.18 Water Quality of the Southeast Ozark Mining, F. Ryck Jr., Missouri Department of Conservation, May 20, 1975

Report evaluates stream conditions of the Southeast Ozark mining area in 1974 based on the diversity of index values benthic macroinvertebrates. Benthic macroinvertebrates were sampled from one steam in the Big River drainage - - Flat River Creek. The report notes that there was dramatic improvement in water quality in Flat River Creek since St. Joe Minerals Corp. shut-down its Federal Division and the remaining tailings were being removed or revegetated. Benthic macroinvertebrate diversity increased from a low of 2.5 in 1971 to 5.8 in 1973 and 1974 and the number of mayfly and stonefly larvae increased from 6 in 1971 to 16 in 1974.

The study area for this report is located in the Old Lead Belt in southeastern Missouri, about 70 miles south of St. Louis. The Old Lead Belt encompasses 110 square miles within the Salem Plateaus physiographic province. The topography is hilly with several hundred feet of relief. The main stream in the area is the Big River, which flows eastward and northward through the study area. The largest tributary the Big River is the Flat River. The Big River is a perennial, gaining stream, whereas Flat River is an intermittent stream that probably loses water to the ground water system immediately after dry periods. The study areas report includes 12 sampling sites on the Big and Flat Rivers both upstream and downstream from the mined areas in the Old Lead Belt.

Surface water discharge was determined on the Big and Flat Rivers at four of the 12 sampling sites. Water-quality samples were collected at the 12 sites quarterly from January 1988 to September 1989. The sites included those on the Big River (site 1,3,6, and 12) and Flat River sites 7 and 11), seeps from tailings piles (sites 2,5,9, and 10), discharge from an abandoned exploration drill hole (site 4), and a site at the base of a tailings pile (site 8). All samples were submitted to the U.S. Geological Survey national water-quality laboratory in Arvada, Colorado, for analysis for 34 inorganic constituents . The analytical results for cadmium ranged from ≤μg/l to 28 μg/l, for lead ≤μg/l to 80 μg/l, and for zinc ≤3μ/l to 18,000 μg/l. Chemical constituents referred to as "dissolved" were determined from samples that were filtered at the time of sampling. Values of specific conductance pH, water temperature, and alkalinity were determined at the time of sampling.

Water-quality and suspended-sediment samples were also collected at high flow at two sites. Results of water-quality analyses of flood samples, include suspended-sediment concentrations and particle-size distribution of suspended-sediment samples. Additional suspended-sediment samples were dried, digested in acid, and then analyzed for total-element contents by inductively coupled plasma by the U.S. Geological Survey, geochemistry laboratory, Denver, Colorado.

Two seepage sampling runs were made in the study area. The first was on September 13, 1989, on the reach of the Big River upstream from State Highway 8 to the Leadwood Public Access and also on the Flat River from Derby to the gaging station below the National tailings pile. The second seepage run was made November 6-8, 2989, on the Big River from the Leadwood Public Access to the Big River below Desloge. Discharge measurements were made to locate stream reaches where surface flow is lost to or gained from the subsurface and water-quality samples were collected to assess the effects of mining. The analytical results for cadmium ranged from ≤1μg/l to 12μg/l, for lead ≤1μg/l to 20μg/l, and from zinc 8μg/l to 2,000μg/l.

120.2.21R Investigation of Clearwater Lake as a Potential Sink for Heavy Metal from Lead Mining in Southeast Missouri

Report provides data on metals concentrations in sediment and biota of Clearwater Lake, which receives most of the surface waters draining the Viburnum Trend, the world's largest lead mining district. The report concludes that the sediments of the lake contain somewhat elevated concentrations of lead, zinc and copper but that under the present conditions these elevated metals concentrations do not constitute an ecological problem.

120.2.22R Uptake of Lead from Aquatic Sediment by Submersed Macrophytes and Crayfish

Report presents data on lead, zinc and cadmium concentrations in muscle (filets), blood and bone tissues and erythrocyte enzyme (ALA-D) activity in Longear Sunfish collected from the Big River and its tributaries during the summer of 1980. The investigation found higher concentrations of lead and cadmium in muscle, lead in blood and lower ALA-D activity at sites affected by tailings than at the control (Irondale) site. There was also some indication of changes in bone tissue associated with exposure to the metals of the sediments. No symptoms of chronic exposure to lead, cadmium or zinc were noted in any fish from the Big River other than ALA-D activity inhibition.

120.2.24R Use of Sequential Extraction to Evaluate the Heavy Metals in Mining Wastes, January 16, 1990

Report presents an evaluation of the availability of metals in tailings from the Old Lead Belt using sequential extraction techniques. The sequential extraction results indicated that the lead was primarily found in residual fraction and probably as PbS. This fraction is thought to be the least available fraction. Some lead was also found in the more available oxide fraction. Copper, zinc and cadmium were found in several different fractions, but primarily in the residual fraction. The author concluded that "the heavy metals in these tailings do appear to be in the more inert form and should not be readily available to the environment unless there is an interaction of the tailings with acids, micro-organisms or chelating materials".

102.2.29R Missouri Stream Pollution Survey, January 1974

Report summarizes stream conditions in the State of Missouri during the period November 1967 to September 1971 based on the results of the Missouri Department of Conservation's state-wide stream pollution survey which was initiated in 1967. The report classified-109.5 miles of the Meramec River System as being seriously polluted. Approximately 88 miles of this pollution was attributed to sewage effluent discharges and the remaining 18 miles was attributed to mining of lead, iron and barite. Four miles of Flat River Creek were classified as seriously polluted by discharges of waste water and mine tailings by the St. Joseph Minerals Corporation Federal Mine.

120.2.30R Fish from Missouri's Lead Belt: To Eat or Not to Eat

Report evaluates fish tissue data collected from 1980 and 1984 in regards to acceptable limits for lead in food. The report notes that elevated concentrations of lead often occur in edible portions of some species of fish, mainly suckers and longear sunfish, at some sites along the Big River and Flat River Creek in the vicinity of abandoned lead mining and milling sites. The report concludes that "the consumption of nominal quantities of contaminated fish from the Big River could contribute sufficient lead to approach or exceed the maximum daily recommended dose promulgated by the WHO. Safety factors built into the WHO recommendations, however, make it improbable that normal adults consuming fish from the Big River would experience lead poisoning."

120.2.31R Lead in Missouri Streams: Monitoring Pollution from Mining with an Assay for Erythrocyte δ-Aminolevulinic Acid Dehydratase (ALA-D) in Fish Blood

Report covers an investigation to verify and calibrate the use of ALA-D activity as a biomarker of lead exposure for use in a state-wide assessment of metal pollution from lead-zinc mining and to determine whether metals other than lead and zinc affect ALA-D activity.

Fish water and sediments were collected from the Old and New Lead Belts and from the Tri-State Mining District. In the Old Lead Belt, the Big River was sampled between Bonne Terre and Desloge. Samples were collected in July of 1989 and January of 1990.

Concentrations of metals were higher in sites affected by mining, with the highest lead concentration in sediments in the Big River. Concentrations of metals in water were low, with many metals below detection limits. Lead, zinc and cadmium concentrations in blood and carcasses varied significantly among locations, with highest concentrations of lead in these media being from the Big River. ALA-D activity was lowest at the sites affected by historic mining activity in the Old Lead Belt (Big River). The results of the investigation suggest that zinc has an ameliorative effect on lead induced ALA-D inactivation and that other metals do not appear to influence ALA-D activity. Based on the results of the investigation the authors of the report recommend measuring ALA-D activity over directly measuring lead concentrations in fish blood in order to estimate lead exposure of Missouri streams fishes, since it is more rapid, less costly, and simpler.

120.2.32R Big River - Big Problem

Report evaluates the problems in the Big River associated with the release of tailings to the stream. The author concludes that the Big River eventually will recover if the erosion of tailings is controlled.

120.2.33R Water Quality Survey of the Southeast Ozark Mining Area, 1972-1973

Report presents an evaluation of water quality in the Southeast Ozark mining area for 1972 and 1973 based on the diversity of benthic macroinvertebrates. The water quality evaluation was initiated in 1965 by the Missouri Department of Conservation. The only site evaluated in the Big River drainage was Flat River Creek. The report notes that there were dramatic improvement in water quality of Flat River Creek since the Federal Division of St. Joe Minerals Corp. ceased operations in the early autumn of 1972.

120.2.34R Use of the Pocketbook Mussel, *Lampsilis Ventricosa*, for Monitoring Heavy Metal Pollution in an Ozark stream, 1987

Report presents the results of an investigation of the accumulation of lead and cadmium by caged pocketbook mussels (Lampsilis ventricosa) placed in the Big River during the summer of 1982. Water and sediment samples were collected from the Big River during the 12-week study period. Mussels were removed at 2,4,8 and 12 weeks from each of the five stations, depurated in flowing water for 3 days and then soft tissues were removed and analyzed for lead and cadmium.

The concentration of lead and cadmium in water, sediment and mussel tissue was found to increase with a downstream progression from Irondale (Control) to Station 5, located downstream of the confluence of Flat River Creek. The highest concentrations of lead (74.2 μg/g) and cadmium (11.3 ppm) in mussel tissue occurred at Station 5 after a 12-week exposure, with the highest lead concentration well below the concentrations reported for endemic mussels from the Big River (386 ppm). It was reported that the concentrations likely had not reached equilibrium with the environment after the 12-week exposure. The author concluded the "the main source of heavy metals contamination to Big River and from the Desloge tailings pond and the ponds and chat piles located within the Flat River drainage basin."

120.2.36R Accumulation of Lead in Fish from Missouri Streams Impacted by Lead Mining, 1985

This study was conducted to determine if elevated levels of lead occur in the edible tissue of fish inhabiting Missouri streams affected by lead mining. The results indicated that the erosion of lead mine tailings into Big River has caused serious environmental degradation to a valuable aquatic resource. This erosion of lead mine tailings into Big River has also resulted in lead levels in suckers which exceed the maximum safe level of lead in the diet.

120.2R.91R Letter on Agricultural Soil Tests to J. Tucker

This study provides soils information for ammonium nitrate, urea formaldehyde, methylated Urea, and calcium nitrate for the purposes of recommending soil additives for plant growth at Desloge. Table A-34 provides soil analysis for N_1, P_2, O_3 K_2O and metals.

120.2.92R Missouri Department of Natural Resources January 27, 1995. Letter to D. Vornberg, Subject: Particulate and Lead per Monitoring Data

1981 - 1982 TSP Data

The maximum value observed for TSP in 1981 was 198 $\mu g/m^3$ and the arithmetic mean was 56 $\mu g/m^3$. The National Ambient Air Quality Standard (NAAQS) for TSP was 260 $\mu g/m^3$ and the secondary standard was 150 $\mu g/m^3$. This has since been replaced by the PM1O standard.

1993 - 1994 Lead Monitoring Data in Air

Lead in air was monitored via high volume air samplers at MO mines in St. Joe Park, the park garage at St. Joe Park, and the southside of St. Joe Park. The maximum value at MO mines in St. Joe Park in 1993 was 0.15 $\mu g/m^3$ and the arithmetic mean was 0.06 $\mu g/m^3$ at MO mines in St. Joe Park in 1994 the maximum value was 0.15 $\mu g/m^3$, and the arithmetic mean was 0.7 $\mu g/m^3$.

TABLE A-34
RESEARCH SOIL ANALYSIS
DESLOGE TAILINGS PILE MISSOURI

							ppm				
							NH^4HCO_3	DTPA EXTRACT			
Sample ID #	pH	—/— EC	Lime% Estimate	O.M.	NO_3-N	P	K	Zn	Fe	Mn	Cu
B1-Jar 1,2,3,4	8.3	0.6	Low	0.7	2	0.9	<1.0	141.0	24.6	3.1	19.3
B2-Jar 1	8.3	0.6	Low	0.6	2	0.6	<1.0	246.0	29.6	3.0	9.6
B2-Jar 3	8.1	2.0	Low	0.7	2	1.8	7.6	42.8	68.5	7.3	17.7
B2-Jar X	8.2	2.0	High	1.3	2	0.9	120.0	83.6	30.4	6.3	1.0
B4-Jar 1,2,3	8.4	0.8	Low	0.6	2	0.6	<1.0	152.0	21.2	3.0	13.7
B4-Jar 4	8.0	1.0	Low	0.7	2	2.1	<1.0	20.7	61.2	8.9	13.5
B5-Jar 1	8.2	0.7	Low	0.7	2	0.6	<1.0	337.0	15.8	1.2	8.1
B5-Jar 3,4,6	8.3	1.1	Low	0.6	2	2.5	<1.0	108.0	29.4	2.3	19.8
B6-Jar 1,2	8.3	0.6	Low	0.7	4	5.9	<1.0	251.0	25.6	1.8	9.8
B6-Jar 3	8.1	0.7	High	0.8	4	<0.2	25.5	456.0	0.9	0.7	15.6
B7-Jar 1,2,3	8.6	0.7	Low	0.7	1	1.5	<1.0	115.0	16.4	1.6	2.3
B7-Jar 4,10	8.1	2.5	Low	0.7	2	<0.2	1.0	69.7	27.9	4.6	0.2
Bag	7.6	4.9	High	0.9	2	0.6	51.4	49.5	67.0	9.0	42.5
P-1Jar 1	8.0	3.0	High	1.1	20	3.0	1.0	354.0	265.0	94.1	59.7
P-Jar 2	8.2	1.3	High	0.8	3	<0.2	38.2	42.6	96.7	7.0	38.3
TP-2Jar 1	8.3	0.4	Medium	0.7	3	0.6	1.0	356.0	23.3	3.7	20.2
Duplicates											
	8.6	0.4	Low	0.7	2	0.6	<1.0	132.0	22.8	2.9	17.3
	8.5	0.7	Low	0.6	1	0.9	<1.0	113.0	16.3	1.7	2.3

TABLE 3-34 (Continued)
RESEARCH SOIL ANALYSIS
DESLOGE TAILINGS PILE MISSOURI

Sample		—meq/l—					—%—			meq/100g
ID #	Ca	Mg	Na	KSAR	Sand	Silt	Clay	Texture	CEC	
B1-Jar 1,2,3,4	2.5	2.2	0.7	1.1	0.4	91	7	2	Sandy	0.4
B2-Jar 1	2.6	2.5	0.5	0.3	0.4	87	11	2	Sandy	0.8
B2-Jar 3	12.5	13.2	0.9	0.7	0.2	34	61	5	Silt Loam	2.0
B2-Jar X	12.6	14.0	0.7	0.8	0.2	0	52	48	Silt Clay	4.8
B4-Jar 1,2,3	3.6	3.3	2.2	0.3	1.2	87	10	3	Sandy	1.6
B4-Jar 4	7.0	4.8	1.0	0.4	0.4	70	27	3	Sandy Loam	1.1
B5-Jar 1	4.8	2.3	0.7	0.3	0.4	91	7	2	Sandy	1.2
B5-Jar 3,4,6	5.0	4.7	3.5	0.6	1.5	66	31	3	Sandy Loam	1.1
B6-Jar 1,2	3.1	2.1	0.6	0.3	0.4	84	13	3	Loamy Sand	1.1
B6-Jar 3	4.6	2.3	1.0	0.4	0.5	20	60	20	Silt Loam	2.1
B7-Jar 1,2,3	2.6	2.5	2.7	0.2	1.7	92	5	3	Sandy	1.0
B7-Jar 4,10	22.0	13.2	2.7	0.7	0.7	66	29	5	Sandy Loam	1.0
Bag	42.4	28.0	3.3	0.9	0.5	17	57	25	Silt Loam	3.7
P-1 Jar 1	24.0	29.6	0.9	0.9	0.2	4	58	38	Silt Clay Loam	IS
TP-1 Jar 2	7.5	6.8	0.5	0.7	0.2	29	55	18	Silt Loam	2.0
TP-2Jar 1	2.3	1.8	0.3	0.2	0.2	66	30	4	Sandy Loam	1.1
Duplicates										
	2.3	2.1	0.5	0.3	0.4					
	2.8	2.8	2.8	0.3	1.7					
						80	10	4	Loamy Sand	1.5
						68	26	8	Sandy Loam	0.9

IS = Insufficient Sample

During 1993 at the park garage in St. Joe Park, the maximum value was 0.23 $\mu g/m^3$. During 1994 at the park garage, the maximum value was 0.10 $\mu g/m^3$.

During 1993 at the southside of St. Joe Park, the maximum value was 0.16 $\mu g/m^3$. During 1994 at the southside, the maximum value was 0.07 $\mu g/m^5$ and the arithmetic mean was 0.06 $\mu g/m^3$.

Additionally, MDNR has provided samples taken via high volume air sampler at 9 locations around St. Joe Park over 4-days (dated as September 30 - October 3, 1992). Lead data appears to be below the 8-hour average NAAQS NESHAPS of 1.5 $\mu g/m^3$.

120.2.93R Report of Analysis (Report No. 55970, Dated 08/31/94) for Stormwater Samples from the Leadwood/Eaton Missouri Tailings site.

The laboratory analysis was performed by Environmental Analysis South. The report was addressed to Marvin Hudwalker of Hudwalker & Associates. The report of analysis is for four samples described as Group 1, 2 and 3, plus an Extra sample. All samples are labeled 08-14-94. The water samples were analyzed in accordance with Standard Methods for the Examination of Water and Wastewater, 17th Edition, 1989; where applicable.

The Group 1 sample was analyzed for B.O.D., C.O.D., nitrogen, nitrate-nitrite, oil and grease, pH, total phosphorus, temperature, total organic carbon, and suspended solids.

The Group 2 sample was analyzed for Sulfates, Acids-Form D, Base/Neutrals-Form D, Dissolved Metals, Pesticides-Form D, Priority Pollutants Table A and Volatiles-Form D. The analysis results shown in Table A-35.

The Group 3 Sample was analyzed for Alkalinity as $CaCo_3$, boron, chloride, fluoride, hardness, settleable solids, sulfates, specific conductance, dissolved solids, suspended solids and total metals. Lead was reported at 0.086 mg/liter.

The Extra sample was analyzed for percent Lead in TSS, fluoride, Kjeldahl Nitrogen, total phosphorus, and total metals. The percent lead in TSS was 0.214% w/w. Lead was reported at 0.046 mg/l.

TABLE A-35
STORMWATER SAMPLES AT LEADWOOD AND EASTON POLLUTANTS

	Dissolved mg/l	Priority Pollutants Tailings Piles
	mg/l	mg/l
Silver	<0.005	<0.005
Arsenic	<0.005	<0.005
Beryllium	<0.005	<0.005
Cadmium	0.007	0.009
Cyanide	ND	<0.005
Chromium	<0.005	<0.005
Copper	<0.005	<0.005
Mercury	<0.0002	<0.0002
Nickel	0.023	0.024
Phenol	ND	0.082
Lead	0.066	<0.03
Antimony	<0.005	<0.005
Selenium	<0.005	<0.005
Thallium	<0.005	<0.005
Zinc	0.218	0.246
ND = No Data		

Source: Hudwalker & Associates, 1994

120.2R.95 Design Analysis and Removal Action Work Plan, Big River Mine Tailings Site, Desloge, Missouri, January 1995.

This document was prepared for The Doe Run Resources Corporation by Fluor Daniel Environment Services. The Design Analysis and Removal Action Work Plan was prepared as required in the United States Environmental Protection Agency, Administrative Order on Consent. The primary purpose of this remediation effort at the Big River Mine Tailings site is to protect against any future tailings discharges, due to slope failures, into the Big River immediately adjacent to the site. This effort will entail the regrading of selected steep slopes contiguous to the river, surface water runoff control, embankment foundation stabilization and protection from flood waters, and the establishment of a self-sustaining vegetative cover.

120.2.2R.86 Jurisdictional Wetland Delineation St. Joe Mineral Corporation Tailings Disposal Site, Leadwood, Missouri, April 1993.

This Jurisdictional Wetland Delineation of the Leadwood tailings disposal site was prepared by Fluor Daniel Environmental Services for the St. Joe Mineral Corporation. The State of Missouri Department of Natural Resources Dam and Reservoir Safety Council granted permission (Construction Permits C-213 and C-214) for St. Joe Minerals to construct alterations to Leadwood Tailings Dam (Mo.30274) and Eaton Tailings Dam (Mo. 31164) on March 3, 1993. The need to add certain improvements may impact lands which have potential for classification as wetlands. To assess potential impacts prior to initiation of construction activities, St. Joe Minerals conducted a wetlands inventory in the areas of potential disturbance.

The St. Joe Minerals Property near Leadwood, Missouri consisted of one large (52 acre) palustrine emergent and shrub wetland between the Leadwood and Eaton Dams. Other ecosystems on the property included wooded slopes, disturbed areas, un-vegetated chat piles and mine tailings disposal areas. The wetland area consisted of about 28 acres of emergent plant species primarily cattail, soft rush and rough horsetail, and 24 acres of willow scrub area. Uplands were dominated by eastern red cedar and oak/dogwood/hornbeam.

The functions and values associated with wetlands is often an important aspect for consideration. Since the wetland is located in a mine tailings disposal area a determination of function and values in relation to toxicant retention is questionable. From general observations the wetlands provides the functions of sediment retention, nutrient transformation, flood water storage and wildlife habitat.

120.2.20R Water Quality of the Southeast Ozark Mining Area & Missouri, August 1981

This report evaluates stream conditions of the southeast Ozark mining area in 1976 and 1978 to 1979 based on the macroinvertebrates. These results are presented along with results from 1965 to 1975, which were summarized in past reports. Flat River Creek in the Big River drainage was one of the streams evaluated. Flat River Creek receives runoff from several inactive lead mine tailings piles. Stream water has been clear after 1973 and the stream bottom was usually free of fine tailings. Invertebrate density and diversity generally improved from 1972 through 1975. Low numbers and diversity in 1976 and 1978 were followed by considerable improvement in 1979, although not yet matching that of the control sample site. This report was prepared by L. Trial and E. F. Robinson-Wilson of the Missouri Department of Conservation.

120.2R.39R Lead Concentrations in Edible Fish Filets Collected from Missouri's Old Lead Belt, 1982

Fish collected from streams and rivers in the Old Lead Belt in Southeast Missouri show Pb concentrations approximately an order of magnitude greater than similar specimens collected from control sites. Species examined included the Black Redhorse Sucker (*Moxostoma duquesni*) Northern Hog Sucker (*Hypentelium negricans*), Longear Sunfish (*leponis magalotio*), Small Mouth Bass (*Micropterus dolomieni*) and Largemouth Bass (*Micropterus Salmoides*). Control lead concentrations in the northern Hog Sucker were 0.07 ppm. Lead concentrations in Northern Hog Sucker from Old Lead Belt Sites ranged from 0.2 to 1.3 ppm. The observed pattern of elevated lead levels exists throughout the Leadwood, Desloge, Flat River and Bonne Terre region served by the Big River and its tributaries. Lead in fish filets appears to be correlated with elevated lead concentrations in stream sediments, although there are apparent anomalies in lead concentrations in sediments and variations in river flow conditions which make it difficult to pinpoint sources and assess correlation between source strength and body burden of lead. Migration habits of the fish species under study further complicate correlation attempts. Lead contamination also appears to be a function of food chain relationships: herbivorous and bottom feeding species carry a heavier burden of lead than carnivorous species which feed higher in the water column. Most species studied showed peak concentrations of lead in midsummer, probably reflecting the effects of low flow conditions, increased benthic productivity, increased feeding, altered feeding habits and higher metabolic rates.

This report was written by N. L. Gale, B. G. Wixson and M. W. McMenus at the University of Missouri - Rolla, Rolla, Missouri.

APPENDIX B

HEALTH AND SAFETY PLAN

INITIAL REMEDIAL INVESTIGATION
BIG RIVER MINE TAILINGS SITES
ST. FRANCOIS COUNTY, MISSOURI

DRAFT
APRIL 1995

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B.1 INTRODUCTION

This section of the site Health and Safety Plan (HASP) document defines general applicability and general responsibilities with respect to compliance with Health and Safety programs.

B.1.1 Scope and Applicability of the Site Health and Safety Plan

The purpose of this site HASP is to define the requirements and designate protocols to be followed at the site during field sampling in support of the remedial investigation (RI) at the Big River Mine Tailings Sites (BRMTS) in St. Francois County, Missouri. The scope of work for field activities covered under this plan include:

- Collection of surficial tailings/chat samples from each of the sites.
- Delineation of areas to which erosion protection is to be applied.
- Visual inspection of each of the tailings impoundments and chat piles
- Collection of upwind and downwind air samples from the Deslodge site. surface.
- General work area clean-up and demobilization.

Applicability extends to all government employees, contractors, subcontractors, and visitors.

All personnel on site, contractors and subcontractors included, shall be informed of the site emergency response procedures and any potential fire, explosion, health, or safety hazards of the operation. This HASP summarizes those hazards in Section B.3.0 and defines protective measures planned for the site.

This plan must be reviewed and an agreement to comply with the requirements must be signed by all personnel prior to entering the exclusion zone or contamination reduction zone.

During development of this plan consideration was given to current safety standards as defined by EPA/OSHA/NIOSH, health effects and standards for known contaminants, and procedures designed to account for the potential for exposure to unknown substances. Specifically, the following reference sources have been consulted:

- OSHA 29 CFR 1910.120 and EPA 40 CFR 311
- U.S. EPA, OERR ERT Standard Operating Safety Guides
- NIOSH/OSHA/USCG/EPA Occupational Health and Safety Guidelines

B.1.2 Visitors

All visitors entering the contamination reduction zone and exclusion zone at the site will be required to read and verify compliance with the provisions of this HASP. In addition, visitors will be expected to comply with relevant OSHA requirements such as medical monitoring (Section B.6), training (Section B.4), and respiratory protection (if applicable). Visitors will also be expected to provide their own protective equipment.

In the event that a visitor does not adhere to the provisions of the HASP, he/she will be requested to leave the work area. All nonconformance incidents will be recorded in the site log.

B.2 KEY PERSONNEL/IDENTIFICATION OF HEALTH AND SAFETY

B.2.1 Key Personnel

The following personnel and organizations are critical to the planned activities at the site. The organizational structure will be reviewed and updated periodically by the site supervisor.

Doe Run
Mr. John Carter, P.E.

Air Sampling Subcontractor
To be determined

Fluor Daniel, Inc.
Michael Saunders, REA

B.2.2 Site Specific Health and Safety Personnel

The Site Health and Safety Officer (HSO) has total responsibility for ensuring that the provisions of this HASP are adequate and implemented in the field. Changing field conditions may require decisions to be made concerning adequate protection programs. Therefore, it is vital that personnel assigned as HSO be experienced and meet the additional training requirements specified by OSHA in 29 CFR 1910.120 (see Section B.4 of this HASP). The HSO is also responsible for conducting site inspections on a regular basis in order to ensure the effectiveness of this plan.

The HSO at the site is to be determined.

Designated alternates include:

- Mr. John Carter

B.2.3 Organizational Responsibility

Doe Run - Responsible for the management of field activities including erosion control/protection work, air monitoring, and coordination with regulatory agencies.

Fluor Daniel, Inc. - Responsible for providing technical support to Doe Run regarding design, field implementation, and health and safety.

B.3 TASK/OPERATION SAFETY AND HEALTH RISK ANALYSIS

This HASP defines the hazards and methods to protect personnel from those hazards as identified in previous site work or background information. The background is presented in Sections 1 through 4 of the RI. A map of the site locations is located in Section 1 of the RI.

Eight sites have been identified where mining activity has resulted in extensive chat piles and/or tailings impoundments. These eight site are:

1. Desloge
2. National
3. Leadwood
4. Elvins/River mines
5. Bonne Terre
6. Federal
7. Doe Run
8. Hayden Creek

In addition to these eight sites, the Big River has also been identified as a "site", although the river is obviously not the location of a pile. The chat/tailings pile at the Deslodge site has been the subject of intense study and therefore additional sampling efforts are not required at this time. The Big River site will not be sampled during this phase of work because it is not considered a source area. Data pertaining to the composition of the chat/tailings for the other sites is erratic. The purpose of sampling the chat/tailings at the site is to demonstrate that the waste products are essentially the same. We believe this to be the case because the lead ore which was the source of the chat and tailings throughout the county was the same deposit, and the benefication processes were identical at all of the sites. The sites which will be subject to sampling during the phase I RI are National, Leadwood, Elvins/River mines), Bonne Terre, Federal, Doe Run, and Hayden Creek. It is believed that at Doe Run and Hayden Creek any tailings/chat piles have been removed, so sampling at these locations will focus on any identifiable footprints from the former piles.

B.3.1 Overview of Site

The sites lie on the eastern edge of the Ozark Highlands, in St. Francois County. The tailings are the result of approximately stockpiling lead mining tailings from mill operations at each of the sites. After ore was processed, tailings were transported via a slurry pipeline and deposited in settling ponds at the site.

The remedial investigation is designed to supplement the existing data on the sites through collection of samples of the tailings at a depth of 0 to 6 inches. These samples will be used to calculate the risk associated with contact of the surface materials at the sites. In addition, upwind and downwind samples of total suspended solids and PM_{10} at the Deslodge site will be made, also to support the risk assessment.

B.3.2 Chemical Hazards

The principal constituent of concern identified in previous studies was lead. In addition, cadmium and zinc have been identified as contaminants of potential concern. Exposure potential to lead and other heavy metals at the site could occur as the result of handling contaminated soils and sediment, equipment contacting contaminated materials, and dusts generated by site activities. This HASP focuses on minimization of exposure to heavy metals by the inhalation, absorption, or ingestion routes by instituting an air monitoring program, requiring adequate PPE, and establishing control measures.

Lead (Pb)

Inorganic lead (CAS # 7439-92-1), includes lead oxides, metallic lead and lead salts. Lead is a blue-gray metal that is soft and malleable. Lead is a cumulative poison and its early effects are nonspecific and, except for laboratory testing, are difficult to distinguish from the symptoms of minor seasonal illnesses. The symptoms are decreased physical fitness, fatigue, sleep disturbance, headache, aching bones and muscles, constipation, abdominal pains, and decreased appetite. Later findings include anemia, pallor, a 'lead line' on the gums, and decreased hand-grip strength. The effects of lead upon the central nervous system (CNS) are the most significant in terms of human health and performance, but occurs only with exposure usually due to ingestion or inhalation of large amounts. Symptoms that result from large exposures include severe headaches, convulsions, coma, delirium, and possibly death. The kidneys can also be damage over long periods of exposure.

The OSHA Permissible Exposure Limit (PEL) for lead dust is 0.05 mg/M^3 and the ACGIH Threshold Limit Value is 0.15 mg/M^3 for an 8-hour Time Weighted Average (TWA), 40-hours per week.

Other constituents of concern include cadmium and zinc.

Cadmium (Cd)

Cadmium has many chemical and physical similarities to zinc and occurs together with zinc in nature. Cadmium occurs in various inorganic salts. Inhalation of cadmium compounds at higher concentration for short periods may lead to chemical pneumonitis and in severe cases pulmonary edema. Symptoms generally occur within 1 to 8 hours after exposure. They are influenza-like and similar to those in metal fume fever. Ingestion of drinks contaminated with cadmium at concentrations exceeding 15mgCd/L gives rise to symptoms of food poisoning. Occupational cadmium exposure has been associated with an increased incidence of prostatic cancer in three different epidemiological studies. However, these studies were not totally conclusive. Available studies suggests an increased risk of respiratory tract cancer.

Other pertinent information regarding Cadmium:

TWA OSHA .2 mg/m3 .6mg/m3 ceiling
TWA NIOSH 40 ug/m3/10 h 200 ug/m3 5 min ceiling
TLV ACGIH .2 MG/M3 (including salts as Cd)

Zinc (Zn)

Zinc is widely distributed in nature in quantities which amount to approximately .02% of the earth's crust. During production processes, the ore is crushed, ground and then upgraded by flotation to produce zinc concentrates containing 50-60% zinc. After roasting to remove sulfur and improve the physical condition of the concentrates, the product is further refined either by smelting, by electrolytic refining, or distillation.

A number of zinc salts may enter the body by inhalation through the skin or by ingestion and produce intoxication. Zinc chloride has been found to cause skin ulcers, and a number of zinc compounds present fire and explosion hazards. Exposure to mists containing sulfuric acid and zinc sulfate evolved during the electrolytic manufacture of zinc has been reported to produce irritation of the respiratory or digestive systems and dental deterioration. Other associated hazards in the metallurgy of zinc arise from the presence of arsenic, cadmium, manganese, lead and possibly chromium and silver. The frequent presence of arsenic in zinc is a source of exposure to arsine whenever zinc is dissolved in acids or alkalis.

Other pertinent information regarding Zinc.

Zinc oxide (ZnO)
TWA OSHA (zinc oxide fumes) 5 mg/m3
NIOSH 15 mg/m3 15 minute ceiling
STEL ACGIH 10 mg/m3

B.3.3 Biologic Hazards

Based on the known history of this site, wastes from hospitals or research facilities handling disease-causing organisms are not anticipated to be found on-site. However, due to the site location and conditions, several biologic hazards may be present. The area around the site is wooded, therefore field operations will be planned with the following hazards in mind:

- Poison ivy
- Poison oak
- Ticks
- Chiggers
- Snakes

Protective clothing, respiratory protection, and pest repellents can help reduce the potential of exposure. Thorough washing of exposed body parts and equipment will help protect against infection.

B.3.4 General Physical Hazards

The site may potentially contain numerous physical hazards. The nature, terrain and location of the site or work activities contribute to many hazards and may include:

- Uneven terrain

- Steep grades
- Slippery surfaces
- Unstable surfaces, such as tailings which may shift, settle, or give way
- Holes or ditches
- Sharp objects
- Hand tools
- Bodies of water, such as the Big River
- Electrical equipment or wires

B.3.5 Heat Stress and Cold Stress

Heat stress is considered a major hazard, especially for workers wearing protective clothing. The same protective materials or equipment that shields the body from chemical exposure or physical injury also limits the dissipation of body heat and moisture. Personal protective clothing can therefore create a potentially hazardous condition. Depending on the ambient conditions and work being performed, heat stress can occur very rapidly.

Cold injury (frostbite and hypothermia) and impaired ability to work are dangers at low ambient temperatures and when the wind-chill factor is low.

Standard operating procedures for both heat stress and cold stress are presented in Attachment 1.

B.3.6 Task by Task Risk Analysis

The evaluation of hazards is based upon the knowledge of site background presented in Section B.3.1, and anticipated risks posed by the specific operation. The following describes each task/operation in terms of the specific hazards associated with it. In addition, the protective measures to be implemented during completion of those operations are also identified.

Task Hazard Descriptions, Tailings Sampling and Air Sampling Activities:

- Terrain or work surface considerations as described under general physical hazards including uneven terrain, steep grades, slippery surfaces, such as tires or geotextiles, unstable surfaces, such as tailings which may shift, settle, or give way, and holes or ditches.

- High pressure/steam cleaning equipment.

- Close proximity to the bodies of water presents a potential drowning hazard.

- Severe weather, such as high winds, high humidity, rain, and lightning.

Hazard Prevention Considerations:

- Proper training and orientation concerning work activities and hazard identification.

- Proper protective clothing such as hand hat, safety glasses/goggles, safety boots, and gloves should be used.

- Routine inspection of equipment and work areas.

- Dust control or suppression during intrusive activities.

- Maintain travel speed suitable for terrain.

- When working adjacent to bodies of water, maintain safety or rescue equipment flotation devices and safety lines. This equipment shall include:

    - A U.S. Coast Guard approved life jacket or buoyant life vest.

    - Ring boys with at least 90 feet of line shall be provided and readily available. (The distance between ring buoys will be less than 200 feet).

- At least one life saving skiff shall be immediately available at locations where employees are working over or adjacent to water.

B.4 PERSONNEL TRAINING REQUIREMENTS

Consistent with OSHA's 29 CFR 1910.120 regulation covering Hazardous Waste Operations and Emergency Response, all site personnel are required to be trained in accordance with the standard. At a minimum, all personnel are required to be trained to recognize the hazards on-site, the provisions of this HASP, and the responsible personnel.

B.4.1 Preassignment and Annual Refresher Training

Prior to arrival on-site, each employer will be responsible for certifying that his/her employees meet the requirements of preassignment training, consistent with OSHA 29 CFR 1910.120 paragraph (e)(3). The employer should be able to provide a document certifying that each general site worker has received 40 hours of instruction off the site, and 24 hours of training for any workers who are on site only occasionally for a specific task. All personnel must also receive 8 hours of refresher training annually.

B.4.2 Site Supervisors Training

Consistent with OSHA 29 CFR 1910.120 paragraph (e)(8), individuals designated as site supervisors require an additional 8 hours of training. The following individuals are identified as site supervisors:

Name	Title/Responsibility
TBD	Field Manager

B.4.3 Training and Briefing Topics

The following items will be discussed by a qualified individual at the site pre-entry briefing(s) or periodic site briefings.

Training	Frequency
Air Monitoring, Sec. 7.0; [29 CFR 1910.120(h)]	(Periodic or daily should be specified)
Animal bites and stings	
Chemical hazards	
Engineering controls and work practices	
Medical surveillance requirements	
Physical hazards	
Respiratory protection, Sec. 5.7	
Structural integrity	
Tools, [29 CFR 1910.242 - .247]	
Training requirements, Sec. 4.0; [29 CFR 1910.120(e)]	

B.5 PERSONAL PROTECTIVE EQUIPMENT TO BE USED

This section describes the general requirements of the EPA designated Levels of Protection (C-D), and the specific levels of protection required for each task at the Site.

B.5.1 Levels of Protection

Personnel wear protective equipment when response activities involve known or suspected atmospheric contamination vapors, gases, or particulates may be generated by site activities, or when direct contact with skin-affecting substances may occur. The specific levels of protection and necessary components for each have been divided into two categories according to the degrees of protection afforded:

Level C: Should be worn when the criteria for using air-purifying respirators are met.

Level D: Should be worn only as a work uniform and not in any area with respiratory or skin hazards. It provides minimal protection against chemical hazards.

Modifications of these levels are permitted, and routinely employed during site work activities to maximize efficiency. For example, Level C respiratory protection and Level D skin protection may be required for a given task. Likewise, the type of chemical protective ensemble (i.e., material, format) will depend upon contaminants and degrees of contact.

The Level of Protection selected is based upon the following:

- Type and measured concentration of the chemical substance in the ambient atmosphere and its toxicity.
- Potential for exposure to substances in air, liquids, or other direct contact with material due to work being done.
- *Knowledge of chemicals on-site along with properties such as toxicity, route of* exposure, and contaminant matrix. In situations where the type of chemical, concentration, and possibilities of contact are not known, the appropriate Level of Protection must be selected based on professional experience and judgment until the hazards can be better identified.

B.5.2 Level C Personnel Protective Equipment

- Air-purifying respirator, full-face, cartridge-equipped (MSHA/NIOSH approved)
- Chemical-resistant clothing (coveralls; hooded, one-piece or two-piece chemical splash suit; chemical-resistant hood and apron; disposable chemical-resistant coveralls)
- Coveralls
- Gloves (outer), chemical-resistant
- Gloves (inner), chemical-resistant
- Boots (outer), chemical-resistant, steel toe and shank
- Boot covers (outer), chemical-resistant (disposable)
- Hard hat (face shield)

- 2-way radio communications (intrinsically safe)

B.5.3 Level D Personnel Protective Equipment

- Coveralls/or basic work uniform
- Gloves
- Boots/shoes, leather or chemical-resistant, steel toe and shank
- Safety glasses
- Hard hat

B.5.4 Reassessment of Protection Program

The Level of Protection provided by PPE selection shall be upgraded or downgraded based upon a change in site conditions or findings of investigations.

When a significant change occurs, the hazards should be reassessed. Some indicators of the need for reassessment are:

- Commencement of a new work phase or work that begins on a different portion of the site.
- Change in job tasks during a work phase.
- Change of season/weather.
- When temperature extremes or individual medical considerations limit the effectiveness of PPE.
- Contaminants other than those previously identified are encountered.
- Change in ambient levels of contaminants.
- Change in work scope which effects the degree of contact with contaminants.

B.5.5 Work Mission Duration

Before the workers actually begin work in their PPE ensembles the anticipated duration of the work mission should be established. Several factors limit mission length, including:

- Suit/Ensemble permeation and penetration rates for chemicals.
- Ambient temperature and weather conditions (heat stress cold stress).
- Capacity of personnel to work in PPE.

B.5.6 Chemical Resistance and Integrity of Protective Material

The following specific clothing materials are recommended for the site:

Sampling/monitoring - (Level D)

- Coveralls
- Gloves
- Boots/shoes
- Safety glasses
- Hardhats

B.5.7 SOP for Respiratory Protection Devices

The following subsections define standard operating procedures for air purifying respirators and self-contained breathing apparatus.

B.5.7.1 Cleaning and Disinfecting Air Purifying Respirators

APRs in routine use should be cleaned and disinfected at least daily. Where respirators are used only occasionally or when they are in storage, the cleaning interval is weekly or monthly, as appropriate.

B.5.7.1.1 Daily Cleaning Procedure

The steps to be followed for cleaning and disinfecting daily are as follows:

- Respirator Disassembly. Respirators are taken to a clean location where the filters, cartridges or canisters are removed, damaged to prevent accidental reuse, and discarded. For thorough cleaning, the inhalation and exhalation valves, speaking diaphragm, and any hoses are removed.

- Cleaning. In most instances, the cleaning and disinfecting solution provided by the manufacturer is used, and is dissolved in warm water in an appropriate tub. Using gloves, the respirator is placed in the tub and swirled for a few moments. A soft brush may be used to facilitate cleaning.

- Rinsing. The cleaned and disinfected respirators are rinsed thoroughly in water to remove all traces of detergent and disinfectant. This is very important for preventing dermatitis.

- Drying. The respirators may be allowed to dry in room air on a clean surface. They may also be hung upside down like drying clothes, but care must be taken not to damage or distort the facepieces.

- Reassembly and Inspection. The clean, dry respirator facepieces should be resembled and inspected in an area separate from the disassembly area to avoid contamination. Special emphasis should be given to inspecting the respirators for detergent or soap residue left by inadequate rinsing. This appears most often under the seat of the exhalation valve, and can cause valve leakage or sticking.

B.5.7.1.2 After Routine Use in Exclusion Zone

The steps to be followed for cleaning and disinfecting in the field are as follows:

- The mask may be washed/rinsed with soap and water.

- At a minimum, the mask should be wiped with disinfectant wipes (benzoalkaloid or isopropyl alcohol), and allowed to air dry in a clean area.

B.5.7.2 APR Inspection and Checkout

1. Visually inspect the entire unit for any obvious damages, defects, or deteriorated rubber.

2. Make sure that the facepiece harness is not damaged. The serrated portion of the harness can fragment which will prevent proper face seal adjustment.

3. Inspect lens for damage and proper seal in facepiece.

4. Exhalation Valve - pull off plastic cover and check valve for debris or for tears in the neoprene valve (which could cause leakage).

5. Inhalation Valves (two) - screw off cartridges/canisters and visually inspect neoprene valves for tears. Make sure that the inhalation valves and cartridge receptacle gaskets are in place.

6. Make sure a protective cover lens is attached to the lens.

7. Make sure the speaking diaphragm retainer ring is hand tight.

8. Make sure that you have the correct cartridge.

9. Don and perform negative pressure test.

B.5.7.3 Storage of Air Purifying Respirators

OSHA requires that respirators be stored to protect against:

- Dust;
- Sunlight;
- Heat;
- Extreme cold;
- Excessive moisture;
- Damaging chemicals; and
- Mechanical damage.

Storage of respirators should be in a clean which minimizes the chance for contamination or unsanitary conditions.

B.5.8 SOP for Personal Protective

B.5.8.1 Inspection

Proper inspection of PPE features several sequences of inspection depending upon specific articles of PPE and the frequency of use. The different levels of inspection are as follows:

- Inspection and operational testing of equipment received from the factory or distributor.
- Inspection of equipment as it is issued to workers.
- Inspection after use or training and prior to maintenance.
- Periodic inspection of stored equipment.
- Periodic inspection when a question arises concerning the appropriateness of the selected equipment, or when problems with similar equipment arise.

TABLE B-5-1
SAMPLE PPE INSPECTION CHECKLISTS

Clothing
Before use: 1. Determine that the clothing material is correct for the specified task at hand. 2. Visually inspect for: - imperfect seams - non-uniform coatings - tears - malfunctioning closures 3. Hold up to light and check for pinholes. 4. Flex product: - observe for cracks - observe for other signs of shelf deterioration 5. If the product has been used previously, inspect inside and out for signs of chemical attack: - discoloration - swelling - stiffness
During the work task: 1. Evidence of chemical attack such as discoloration, swelling, stiffening, and softening. Keep in mind, however, that chemical permeation can occur without any visible effects. 2. Closure failure. 3. Tears. 4. Punctures. 5. Seam Discontinuities.
Gloves
Before use: 1. Visually inspect for: - imperfect seams - tears - non-uniform coating - pressurize glove with air; listen for pin-hole leaks.

The primary inspection of PPE in use for activities at the Site will occur prior to immediate use and will be conducted by the user. This ensures that the specific device or article has been checked-out by the user that the user is familiar with its use.

B.5.9 Specific Levels of Protection Planned for the Site

The following levels of protection will be utilized during activities at the site:

- It is anticipated that all tasks can be conducted in Level D protection. In the event that air monitoring requires additional protection, workers will upgrade to Level C protection or exit the work area until air monitoring indicates that work can continue under Level D protection.

Actual task levels of protection or PPE will be selected and modified in the field as determined by the HSO.

B.6 MEDICAL SURVEILLANCE REQUIREMENTS

Medical monitoring programs are designed to track the physical condition of employees on a regular basis as well as survey preemployment or baseline conditions prior to potential exposures. The medical surveillance program is a part of each employers Health and Safety program.

B.6.1 Baseline or Preassignment Monitoring

Prior to being assigned to a hazardous or a potentially hazardous activity involving exposure to toxic materials employee must receive a preassignment or baseline physical. The contents of the physical is to be determined by the employers medical consultant. As suggested by NIOSH/OSHA/USCG/EPA's Occupational Safety & Health Guidance Manual for Hazardous Waste Site Activities, the minimum medical monitoring requirements for work at the Site is as follows:

- Complete medical and work histories
- Physical examination

- Pulmonary function tests (FVC and FEV1)
- Chest X-ray (every 2 years)
- EKG
- Eye examination and visual acuity
- Audiometry
- Urinalysis
- Blood chemistry and heavy metals toxicology

The preassignment physical should categorize employees as fit-for-duty and able to wear respiratory protection.

B.6.2 Periodic Monitoring

In addition to a baseline physical, all employees require a periodic physical within the last 12 months unless the advising physician believes a shorter interval is appropriate. The employers medical consultant should prescribe an adequate medical which fulfills OSHA 29 CFR 1910.120 requirements. The preassignment medical outlined above may be applicable.

All personnel working in contaminated or potentially contaminated areas at the Site will verify currency (within 12 months) with respect to medical monitoring. This is done by indicating date of last physical on the safety plan agreement form.

B.6.3 Site Specific Medical Monitoring

For activities at the Site, the following specific tests will be required prior to individuals entering the Exclusion Zone or Contamination Reduction Zone.

B.6.4 Exposure/Injury/Medical Support

As a follow-up to an injury or possible exposure above established exposure limits, all employees are entitled to and encouraged to seek medical attention and physical testing. Depending upon the type of exposure, it is critical to perform follow-up testing within 24-48 hours. It will be up to the employer's medical consultant to advise the type of test required to accurately monitor for exposure effects.

B.6.5 Exit Physical

At termination of employment or reassignment to an activity or location which does not represent a risk of exposure to hazardous substances, an employee shall require an exit physical. If his/her last physical was within the last 6 months, the advising medical consultant has the right to determine adequacy and necessity of exit exam.

B.7 FREQUENCY AND TYPES OF AIR MONITORING/SAMPLING

This section explains the general concepts of an air monitoring program and specifies the surveillance activities that will take place during project completion at the Site.

The purpose of air monitoring is to identify and quantify airborne contaminants in order to verify and determine the level of worker protection needed. Initial screening for identification is often qualitative, i.e., the contaminant, or the class to which it belongs, is demonstrated to be present but the determination of its concentration (quantification) must await subsequent testing. Air monitoring at the site will utilize:

- The onsite use of direct-reading instruments.

B.7.1 Direct-Reading Monitoring Instruments

Unlike air sampling devices, which are used to collect samples for subsequent analysis in a laboratory, direct-reading instruments provide information at the time of sampling, enabling rapid decision-making. Data obtained from the real-time monitors are used to assure proper selection of personnel protection equipment, engineering controls, and work practices. Overall, the instruments provide the user the capability to determine if site personnel are being exposed to concentrations which exceed exposure limits or action levels for specific hazardous materials.

Real-time monitors can be useful in identifying airborne contaminants and flammable atmospheres. Periodic monitoring of conditions is critical, especially if exposures may have increased since initial monitoring or if new site activities have commenced. The following provides an overview of available monitoring instrumentation and their specific operating parameters.

Instrument: Real Time Aerosol Monitor

Hazard Monitored: Particulates

Application: Measures total particulates in air.

Detection Method: Uses an internal light source. The particulates defract the light beam and the amount of diffraction is converted into concentration (mg/m^3).

General Care/Maintenance: Recharge batteries. Replace desiccant when necessary.

Typical Operating Time: 8-12 hours.

B.7.2 Chemical Exposure Monitoring

According to guidance documents there are three metals of concern at this site. Using a conservative approach the concentrations that we refer to will be the highest found in past sampling events. Using the highest concentrations will present a worst case scenario and will include an initial safety factor for all calculations to follow.

The following information is derived from highest recorded concentrations from past sampling results:

Lead	13,000 mg/kg
Cadmium	270 mg/kg
Zinc	13,000 mg/kg

Using the information in Section B.3.2 the concentration of Lead in air would appear to be of the greatest concern for this site.

B.7.3 Action Level

Using the worst case scenario, if 100% of the soil were to become airborne, approximately 1.3% of this airborne solid would be lead dust. Expressed as a percentage, 1.3% of the soil is lead. Lead airborne exposure limit of .05mg/m3 is divided by this percentage to estimate the level of total particulate suspension that is required to equal the exposure limit. In this case it is 3.9 mg/m3. Again, using a worst case scenario and building in another safety factor of approximately two to give an action level of 2 mg/m3.

(NOTE: If action levels are exceeded, this plan will be expanded to include: respiratory protection, medical surveillance, Personal protective equipment, hygiene facilities, signage, and all aspects of OSHA 1910.1025 or 1926.62)

B.7.4 Air Sampling

Mini-Ram monitoring will take place in the breathing zone of workers. For work in the tailings area, reading approaching 2 mg/m3 will require dust suppression to reduce dust levels. If dust suppression is ineffective or unavailable or dust levels continue to exceed the action levels workers will don approve respiratory equipment such as full face APRs with appropriate cartridges/filters or other approved devices. (NOTE: see comment in Section B.7.3 above).

B.8 SITE CONTROL MEASURES

The following section defines measures and procedures for maintaining site control. Site control is an essential component in the implementation of the site health and safety program.

B.8.1 Buddy System

A buddy system requires at least two people who work as a team; each looking out for each other. For example, sampling operations generally require two people.

B.8.2 Site Communications Plan

Successful communications between field teams and contact with personnel in the support zone is essential. The following communications systems will be available during activities at the Site.

- Hand Signals

Signal	Definition
Hands clutching throat	Out of air/cannot breath
Hands on top of head	Need assistance
Thumbs up	OK/I am alright/I understand
Thumbs down	No/negative
Arms waving upright	Send backup support
Grip partners wrist	Exit area immediately

B.8.3 Work Zone Definition

The three general work zones will be established at each site. These are the Exclusion Zone, Contamination Reduction Zone, and Support Zone.

The Exclusion Zone is defined as the area where contamination is either known or likely to be present, or because of activity, will provide a potential to cause harm to personnel. Entry into the Exclusion Zone requires the use of personnel protective equipment.

The Contamination Reduction Zone is the area where personnel conduct personal and equipment decontamination. It is essentially a buffer zone between contaminated areas and clean areas. Activities to be conducted in this zone will require personal protection as defined in the decontamination plan.

The Support Zone is situated in clean areas where the chance to encounter hazardous materials or conditions is minimal. Personal protective equipment is therefore not required.

B.8.4 Nearest Medical Assistance

The nearest medical facility which can provide emergency care for individuals who may experience an injury or exposure will be determined on a site by site basis by the HSO. The route to the hospital should be verified by the HSO on a site by site basis, and should be familiar to all site personnel.

The following individuals on-site have current certification in CPR and/or first aid:

- TBD

B.8.5 Safe Work Practices

Table B-8-1 provides a list of standing orders for the Exclusion Zone.

Table B-8-2 provides a list of standing orders for the Contamination Reduction Zone.

B.8.6 Emergency Alarm Procedures

The warning signals described in Section B.10.4 "Evacuation Routes and Procedures," will be deployed in the event of an emergency. Communication signals will also be used according to Section B.8.2.

TABLE B-8-1
STANDING ORDERS FOR EXCLUSION ZONE

• No smoking, eating, or drinking in this zone.
• No horse play.
• No matches or lighters in this zone.
• Check-in on entrance to this zone.
• Check-out on exit from this zone.
• Implement the communications system.
• Line of sight must be in position.
• Wear the appropriate level of protection as defined in the Safety Plan.

TABLE B-8-2
STANDING ORDERS FOR CONTAMINATION REDUCTION ZONE

• No smoking, eating, or drinking in this zone.
• No horse play.
• No matches or lighters in this zone.
• Wear the appropriate level of protection.

B.9 DECONTAMINATION PLAN

The tasks and specific levels of protection required for each task are discussed in Section B.5.9. Consistent with the levels of protection required, the decontamination figure 9-1 provides a step by step representation of the personnel decontamination process for either level A, B, or C. These procedures should be modified to suit site conditions and protective ensembles in use.

B.9.1 Standard Operating Procedures

Decontamination involves the orderly controlled removal of contaminants. Standard decontamination sequences are presented in the decontamination figure. All site personnel should minimize contact with contaminants in order to minimize the need for extensive decontamination.

B.9.2 Levels of Decontamination Protection Required for Personnel

The levels of protection required for personnel assisting with decontamination is anticipated to be Level D, dependent on monitoring results.

The Site Safety Officer is responsible for monitoring decontamination procedures and determining their effectiveness.

B.9.3 Equipment Decontamination

All equipment utilized on-site shall be free of soils or other materials. Materials which cannot be removed by brushing shall be spray-washed prior to release from the site.

B.9.4 Disposition of Decontamination Wastes

All equipment and solvents used for decontamination shall be decontaminated or disposed of properly. Commercial laundries or cleaning establishments that decontaminate protective clothing or equipment shall be informed of the potentially harmful effects of exposures.

FIGURE B-9-1
LEVEL C DECONTAMINATION STEPS

Step 1 Segregated equipment drop
Step 2 Boot cover and glove wash
Step 3 Boot cover and glove rinse
Step 4 Tape removal
Step 5 Boot cover removal
Step 6 Outer glove removal
Step 7 Suit/safety boot wash
Step 8 Suit/safety boot rinse
Step 9 Safety boot removal
Step 10 Splash suit removal
Step 11 Inner glove wash
Step 12 Inner glove rinse
Step 13 Face piece removal
Step 14 Inner glove removal
Step 15 Inner clothing removal
Step 16 Field wash
Step 17 Redress

B.10 EMERGENCY RESPONSE/CONTINGENCY PLAN

This section describes contingencies and emergency planning procedures to be implemented at the Site. This plan is compatible with local, state and federal disaster and emergency management plans as appropriate.

B.10.1 Pre-Emergency Planning

During the site briefings held periodically/daily, all employees will be trained in and reminded of provisions of the emergency response plan, communication systems, and evacuation routes. Table B-10-1 identifies the hazardous conditions associated with specific site activities. The plan will be reviewed and revised, if necessary, on a regular basis by the HSO. This will ensure that the plan is adequate and consistent with prevailing site conditions.

B.10.2 Personnel Roles and Lines of Authority

The Site Supervisor has primary responsibility for responding to and correcting emergency situations. This includes taking appropriate measures to ensure the safety of site personnel and the public. Possible actions may involve evacuation of personnel from the site area, and evacuation of adjacent residents. He/she is additionally responsible for ensuring that corrective measures have been implemented, appropriate authorities notified, and follow-up reports completed. The HSO may be called upon to act on the behalf of the site supervisor, and will direct responses to any medical emergency. The individual contractor organizations are responsible for assisting the project manager in his/her mission within the parameters of their scope of work.

The Site Supervisor is John Carter, P.E., Field Manager

The HSO is Joey Tucker.

B.10.3 Emergency Recognition/Prevention

The anticipated chemical and physical hazards have been discussed in Section B.3.0. Additional hazards as a direct result of site activities are listed in Table B-10-1 as are prevention and control techniques/mechanisms. Personnel will be familiar with techniques of hazard recognition from preassignment training and site specific briefings. The HSO is responsible for ensuring that prevention devices or equipment is available to personnel.

B.10.4 Evacuation Routes/Procedures

In the event of an emergency which necessitates an evacuation of the site, the following emergency procedures will be implemented:

Personnel will be expected to proceed to the closest exit with their buddy, and mobilize to the safe distance area associated with the evacuation route. Personnel will remain at that area until the Re-entry alarm is sounded or an authorized individual provides further instructions.

TABLE B-10-1
EMERGENCY RECOGNITION/CONTROL MEASURES

Hazard	Prevention/Control	Location
Air Release	Water Spray on cassation of activities	At the immediate work area

B.10.5 Emergency Contact/Notification System

The following list provides names and telephone numbers for emergency contact personnel. In the event of a medical emergency, personnel will take direction from the HSO and notify the appropriate emergency organization. In the event of fire or spill, the site supervisor will notify the appropriate local, state, and federal agencies.

Organization	Contact	Telephone
Ambulance:		
Police:	Local-TBD	
Fire:	Local-TBD	
State Police:	MO Highway Patrol	314-340-4000
Hospital 1:	TBD	
Hospital 2:	TBD	
Poison Control Center:	TBD	
Regional EPA:		
EPA Emergency Response Team:		908-321-6660
State Authority:		
National Response Center:		800-424-8802
Center for Disease Control:		404-488-4100
Chemtrec:		800-424-9555

B.10.6 Emergency Medical Treatment Procedures

Any person who becomes ill or injured in the exclusion zone must be decontaminated to the maximum extent possible. If the injury or illness is minor, full decontamination should be completed and first aid administered prior to transport. If the patient's condition is serious, at least partial decontamination should be completed (i.e., complete disrobing of the victim and redressing in clean coveralls or wrapping in a blanket.) First aid should be administered while awaiting an ambulance or paramedics. All injuries and illnesses must immediately be reported to the project manager.

Any person being transported to a clinic or hospital for treatment should take with them information on the chemical(s) they have been exposed to at the site. At this time lead is considered the principal contaminant of concern.

Any vehicle used to transport contaminated personnel will be treated and cleaned as necessary.

B.10.7 Fire or Explosion

In the event of a fire or explosion, the local fire department should be summoned immediately. Upon their arrival, the project manager or designated alternate will advise the fire commander of the location, nature, and identification of the hazardous materials onsite.

If it is safe to do so, site personnel may:

- Use fire fighting equipment (extinguishing equipment meeting 29CFR Part 1910 Subpart 1) available onsite to control or extinguish the fire; and,

- Remove or isolate flammable or other hazardous materials which may contribute to the fire.

B.10.8 Spill or Leaks

In the event of a spill or a leak, site personnel will:

- Inform their supervisor immediately;
- Locate the source of the spillage and stop the flow if it can be done safely; and,
- Begin containment and recovery of the spilled materials.

B.10.9 Emergency Equipment/Facilities

- First aid kit
- Cellular Telephone
- Emergency Horn

B.11 CONFINED SPACE ENTRY PROCEDURES

Although confined space entries are not anticipated at this time, the following discussion is presented in the event that changes in site conditions or work activities does occur.

A confined space provides the potential for unusually high concentrations of contaminants, explosive atmospheres, limited visibility, and restricted movement. This section will establish requirements for safe entry into, continued work in, and safe exit from confined spaces. Additional information regarding confined space entry can be found in 29 CFR 1926.21, 29 CFR 1910 and NIOSH 80-106.

B.11.1 Definitions

Confined Space: A space or work area not designed or intended for normal human occupancy, having limited means of egress and poor natural ventilation; and/or any structure, including buildings or rooms, which have limited means of egress.

Confined Space Entry Permit (CSEP): A document to be initiated by the supervisor of personnel who are to enter into or work in a confined space. The CSEP will be completed by the personnel involved in the entry and approved by the HSO before personnel will be permitted to enter the confined space. The CSEP shall be valid only for the performance of the work identified and for the location and time specified. The beginning of a new shift with change of personnel will require the issuance of a new CSEP.

Confined Space Observer: An individual assigned to monitor the activities of personnel working within a confined space. The confined space observer monitors and provides external assistance to those inside the confined space. The confined space observer summons rescue personnel in the event of emergency and assists the rescue team.

B.11.2 General Provisions

- When possible, confined spaces should be identified with a posted sign which reads: Caution - Confined Space.

- Only personnel trained and knowledgeable of the requirements of these Confined Space Entry Procedures will be authorized to enter a confined space or be a confined space observer.

- A CSEP must be issued prior to the performance of any work within a confined space. The CSEP will become a part of the permanent and official record of the site.

- Natural ventilation shall be provided for the confined space prior to initial entry and for the duration of the CSEP. Positive/forced mechanical ventilation may be required. However, care should be taken to not spread contamination outside of the enclosed area.

- If flammable liquids may be contained within the confined space, explosion proof equipment will be used. All equipment shall be positively grounded.

- The contents of any confined space shall, where necessary, be removed prior to entry. All sources of ignition must be removed prior to entry.

- Hand tools used in confined spaces shall be in good repair, explosion proof and spark proof, and selected according to intended use. Where possible, pneumatic power tools are to be used.

- Hand-held lights and other illumination utilized in confined spaces shall be equipped with guards to prevent contact with the bulb and must be explosion proof.

- Compressed gas cylinders, except cylinders used for self-contained breathing apparatus, shall not be taken into confined spaces. Gas hoses shall be removed from the space and the supply turned off at the cylinder valve when personnel exit from the confined space.

- If a confined space requires respiratory equipment or where rescue may be difficult, safety belts, body harnesses, and lifelines will be used. The outside observer shall be provided with the same equipment as those working within the confined space.

- A ladder is required in all confined spaces deeper than the employee's shoulders. The ladder shall be secured and not removed until all employees have exited the space.

- Only self-contained breathing apparatus or NIOSH approved airline respirators equipped with a 5-minute emergency air supply (egress bottle) shall be used in untested confined spaces or in any confined space with conditions determined immediately dangerous to life and health.

- Where air-moving equipment is used to provide ventilation, chemicals shall be removed from the vicinity to prevent introduction into the confined space.

- Vehicles shall not be left running near confined space work or near air-moving equipment being used for confined space ventilation.

- Smoking in confined spaces will be prohibited at all times.

- Any deviation from these Confined Space Entry Procedures requires the prior permission of the On-Scene Coordinator.

B.11.3 Procedure for Confined Space Entry

The HSO and Entry Team shall:

- Evaluate the job to be done and identify the potential hazards before a job in a confined space is scheduled.
- Ensure that all process piping, mechanical and electrical equipment, etc., have been disconnected, purged, blanked-off or locked and tagged as necessary.
- If possible, ensure removal of any standing fluids that may produce toxic or air displacing gases, vapors, or dust.
- Initiate a CSEP in concurrence with the project manager or designated alternative.
- Ensure that any hot work (welding, burning, open flames, or spark producing operation) that is to be performed in the confined space has been approved by the project manager and is indicated on the CSEP.
- Ensure that the space is ventilated before starting work in the confined space and for the duration of the time that the work is to be performed in the space.
- Ensure that the personnel who enter the confined space and the confined space observer helper are familiar with the contents and requirements of this instruction.
- Ensure remote atmospheric testing of the confined space prior to employee entry and before validation/revalidation of a CSEP to ensure the following:

    1. Oxygen content between 19.5% - 23.0%.
    2. No concentration of combustible gas in the space. Sampling will be done throughout the confined space and specifically at the lowest point in the space.

3. The absence of other atmospheric contaminants space has contained toxic, corrosive, or irritant material.

4. If remote testing is not possible, Level B PPE is required.

- Designate whether hot or cold work will be allowed. If all tests are satisfactory, complete the CSEP listing any safety precautions, protective equipment, or other requirements.

- Ensure that a copy of the CSEP is posted at the work site, a copy is filed with the project supervisor, and a copy is furnished to the project manager.

The CSEP shall be considered void if work in the confined space does not start within one hour after the tests are performed or if significant changes within the confined space atmosphere or job scope occurs.

The CSEP posted at the work site shall be removed at the completion of the job or the end of the shift, whichever is first.

B.11.4 Confined Space Observer

- While personnel are inside the confined space, a confined space observer will monitor the activities and provide external assistance to those in the space. The observer will have no other duties which may take his attention away from the work or require him to leave the vicinity of the confined space at any time while personnel are in the space.

- The confined space observer shall maintain at least voice contact with all personnel in the confined space. Visual contact is preferred, if possible.

- The observer shall be instructed by his supervisor in the method for contacting rescue personnel in the event of an emergency.

- If irregularities within the space are detected by the observer, personnel within the space will be ordered to exit.

- In the event of an emergency, the observer must NEVER enter the confined space prior to contacting and receiving assistance from a helper. Prior to this time, he should attempt to remove personnel with the lifeline and to perform all other rescue functions from outside the space.

- A helper shall be designated to provide assistance to the confined space observer in case the observer must enter the confined space to retrieve personnel.

B.12 HAZARD COMMUNICATION

In order to comply with 29 CFR 1910.1200, Hazard Communication, the following written Hazard Communication Program has been established. All employees will be briefed on this program, and have a written copy for review.

A. Container Labeling

All containers received on site will be inspected to ensure the following: (1) all containers will be clearly labeled as to the contents; (2) the appropriate hazard warnings will be noted; and (3) the name and address of the manufacturer will be listed.

All secondary containers will be labeled with either an extra copy of the original manufacturer's label or with generic labels which have a block for identity and blocks for the hazard warning.

B. Material Safety Data Sheets (MSDSs)

Copies of MSDSs for all hazardous chemicals known or suspected on site will be maintained in the work area. MSDSs will be available to all employees for review during each work shift.

C. Employee Training and Information

Prior to starting work, each employee will attend a health and safety orientation and will receive information and training on the following: (1) an overview of the requirements contained in the Hazard Communication Standard, 29 CFR 1910.1200; (2) chemicals present in their workplace operations; (3) location and availability of a written hazard program; (4) physical and health effects of the hazardous chemicals; (5) methods and observation techniques used to determine the presence or release of hazardous chemicals; (6) how to lessen or prevent exposure to these hazardous chemicals through usage of control/work practices and personal protective equipment; (7) emergency procedures to follow if they are exposed to these chemicals; (8) how to read labels and review MSDSs to obtain appropriate hazard information; (9) location of MSDS file and location of hazardous chemical list.

Fluor Daniel
Environmental Services

Old Lead Belt
Remedial Investigation

Date ____/____/____

Air Monitoring Results

Contaminant: particulate

Weather: ____________

Action Level: 2 mg/m^3

Instrument: ____________

Time	Readings	Time	Readings

Sketch of Work Area, Monitor Location, and Wind Direction

Name: ____________

Signature: ____________

Fluor Daniel
Environmental Services

Old Lead Belt
Remedial Investigation

Date ____/____/____
Time ____________

Toolbox Safety Meeting

Site Health Officer: ____________________

Attendees:

Topic:

Were all attendees properly dressed/equipped? ____________________
Any deficiencies? ____________________
Describe corrective measures: ____________________

ATTACHMENT B.I
HEAT STRESS
STANDARD OPERATING PROCEDURES

Field operations during the summer months can create a variety of hazards to the employee. Heat cramps, heat exhaustion, and heat stroke can be experienced, and if not remedied, can threaten life or health. Therefore, it is important that all employees be able to recognize symptoms of these conditions and be capable of stopping the problem as quickly as possible.

B.I.1 The Effects of Heat

As the result of normal oxidation processes within the body, a predictable amount of heat is generated. If the heat is released as it is formed, there is no change in body temperature. If the heat is released more rapidly, the body cools to a point at which the production of heat is accelerated and the excess is available to bring the body temperature back to normal.

Interference with the elimination of heat leads to its accumulation and thus to the elevation of body temperature. As a result, the person is said to have a fever. When such a condition exists, it produces a vicious cycle in which certain body processes speed up and generate additional heat. Then the body must eliminate not only the normal but also the additional quantities of heat.

Heat produced within the body is brought to the surface largely by the bloodstream and escapes to the cooler surroundings by conduction and radiation. If air movement or a breeze strikes the body, additional heat is lost by convection. However, when the temperature of the surrounding air becomes equal to or rises above that of the body, all of the heat must be lost by vaporization of the moisture or sweat from the skin surface. As the air becomes more humid (contains more moisture), vaporization from the skin slows down. Thus, on a day when the temperature is 95 to 100°F, with high humidity and little or no breeze, conditions are ideal for the storage of heat within the body. It is on such a day, or more commonly a succession of such days (a heat wave), that medical emergencies due to heat are likely to occur. Such emergencies are classified in four categories: heat rash, heat cramps, heat exhaustion, and heat stroke.

Heat Rash

Heat rash is caused by continuous exposure to heat and humid air and aggravated by chafing clothes. It also decreases the individual's ability to tolerate heat.

Control of Heat Rash. Change wet or damp clothing often. Use talcum or medicated talcum powder to control chaffing and rash.

Heat Cramps

Heat cramps usually affect people who work in hot environments and perspire a great deal. Loss of salt from the body causes very painful cramps of the leg and abdominal muscles. Heat cramps also may result from drinking iced water or other drinks either too quickly or in too large a quantity.

The symptoms of heat cramps are:

- Muscle cramps in legs and abdomen,
- Pain accompanying the cramps,
- Faintness, and
- Profuse perspiration.

Heat Cramp Emergency Care. Remove the patient to a cool place. Give them sips of liquids such as "Gatorade" or its equivalent. Apply manual pressure to the cramped muscle. Remove the patient to a hospital if there is any indication of a more serious problem.

Heat Exhaustion

Heat exhaustion occurs in individual's working in hot environments, and may be associated with heat cramps. Heat exhaustion is caused by the pooling of blood in the vessels of the skin. The heat is transported from the interior of the body to the surface by the blood. The blood vessels in the skin become dilated and a large amount of blood is pooled in the skin. This condition, plus the blood pooled in the lower extremities when an individual is in an upright position, may lead to an inadequate return of blood to the heart and eventually to physical collapse.

The symptoms of heat exhaustion are:

- Weak pulse,
- Rapid and usually shallow breathing,
- Generalized weakness,
- Pale, clammy skin,
- Profuse perspiration,
- Dizziness,
- Unconsciousness, and
- Appearance of having fainted (the patient responds to the same treatment administered in cases of fainting).

Heat Exhaustion Emergency Care. Remove the patient to a cool place and remove as much clothing as possible. Administer cool water, "Gatorade," or its equivalent. If possible, fan the patient continually to remove heat by convection, but do not allow chilling or overcooling. Treat the patient for shock, and remove to a medical facility if there is any indication of a more serious problem.

Heat Stroke

Heat stroke is a profound disturbance of the heat-regulating mechanism, associated with high fever and collapse. Sometimes this conditions results in convulsions, unconsciousness, and even death. Direct exposure to sun, poor air circulation, poor physical condition, and advanced age (over 40) bear directly on the tendency to heat stroke. It is a serious threat to life and carries a 20% mortality rate. Alcoholics and overweight persons are extremely susceptible.

The symptoms of heat stroke are:

- Sudden onset,
- Dry*, hot, and flushed skin,
- Dilated pupils,
- Early loss of consciousness,
- Full and fast pulse,
- Breathing deep at first, later shallow and almost absent,
- Muscle twitching, growing into convulsions, and
- Body temperature reaching 105 to 106°F or higher.

* Note: Personnel wearing vapor barrier protective clothing may not show dry skin. Their skin may be completely wetted with perspiration produced earlier.

Heat Stroke Emergency Care. Remember that this is a true emergency. Transportation to a medical facility should not be delayed. Remove the patient to a cool environment if possible, and remove as much clothing as possible. Assure an open airway. Reduce body temperature promptly-preferably by wrapping in a wet sheet or else by dousing the body with water. If cold packs are available, place them under the arms, around the neck, at the ankles, or at any place where blood vessels that lie close to the skin can be cooled. Protect the patient from injury during convulsions, especially from tongue biting.

B.I.2 Avoidance of Heat-Related Emergencies

Note that, in the case of heat cramps or heat exhaustion, "Gatorade" or its equivalent is suggested as part of the treatment regime. The reason for this type of liquid refreshment is that such beverages will return much-needed electrolytes (salts) to the system. Without these electrolytes, body systems cannot function properly, thereby increasing the potential health hazard. Therefore, when personnel are working in situations where the ambient temperatures and humidity are high - and especially in situations where protection Levels A, B, and C are required - the site safety officer must:

- Revise work schedules, when necessary, to take advantage of the cooler parts of the day (i.e., 5 a.m. to 1 p.m., and 6 p.m. to nightfall).

- Assure that workers are acclimated before allowing them to work for extended periods. Heat induces a series of physiological and psychological stresses that the individual worker must adjust to during the first week of heat exposure. Workers should slowly work into their peak work performance over a two-week period. Workers absent from the site for several days must be allowed to become reacclimated.

- Only physically fit and medically qualified workers shall be permitted to work on-site, especially in a heat stress setting. Persons with hangovers, feeling ill, running even a minor fever, or those on severe weight reduction diets shall not be allowed to work.

- Reduce manual labor by mechanizing tasks. Using a backhoe instead of shoveling or using a crane to lift or move drums are examples of how mechanization can be used to reduce heat stress.

- Reduce the amount of time employees are working in a hot environment. Work/rest periods should be developed according to the results for the worker monitoring program. Other methods to reduce the employee exposure time include rotating personnel, performing work during cooler hours of the day, or adding personnel to work teams.

- Modify the thermal environment or shielding. Control of radiant heat gain is best accomplished by shielding. An example would be an umbrella to shade the worker from the sun (e.g., commercially available umbrellas from heavy equipment operations). Reducing heat gain from convection may be accomplished by supplying cooler air to the work environment. As a minimum, break areas, locker rooms, and lunchrooms should be located in shaded areas.

- Reduce the temperature of the rest area. The rest area should be maintained at a temperature of approximately 77°F.

- Replace fluids. Water and "Gatorade" type drinks should be available to employees so that fluid lost by sweating is replaced. Employees should be encouraged to drink more fluids when working in hot environments, since normal thirst mechanisms are not always sensitive enough to ensure adequate fluid replacement.

- Encourage workers to eat lightly at lunchtime and to eat cool meals rather than hot.

- Worker oral temperature shall never be allowed to rise above 100°F. If such an elevation occurs, worker will be required to remain in the rest area until their temperature falls below 99°F, and following work shifts shall be shortened and/or modified to prevent a recurrence.

- Special control measures will be required if WBGT temperatures exceed the limiting values. These special controls may include personal ice cooling vests and/or venturi air cooling devices.

B.I.3 Work-Rest Regimen

In order to establish a proper work-rest regimen, the WBGT will be used in conjunction with an assessment of the work load required to perform each task. Examples of light work include sitting or standing to control machines or performing light hand or arm work. Moderate work includes walking about with moderate lifting and pushing or using coated protective coveralls and respirators. Heavy work corresponds to pick and shovel-type work or the use of full-body protective clothing. It must be assumed that any activity involving this type of clothing will be considered heavy work.

The work-rest regimen selected using the WBGT procedure will be used as a daily baseline, as per Section B.1.3.2. The actual or adjusted period of work will be determined based on the Worker Monitoring outlined in Section B.1.4 of this procedure.

WBGT Determination

In order to determine the WBGT the following equations will be used:

- Outdoors with solar load:
  WBGT = 0.7 WB + 0.2 GT + 0.1 DB

- Indoors or outdoors with no solar load:
  WBGT = 0.7 WB + 0.3 GT

  Where:

WBGT	=	Wet Bulb Globe Temperature Index
WB	=	Natural Wet-Bulb Temperature
DB	=	Dry-Bulb Temperature
GT	=	Globe Thermometer Temperature

The factors involved in the above equations may be measured with the use of a direct-reading heat stress monitor capable of measuring all of the individual factors associated with the WBGT equation (e.g., the Reuter-Strokes Wibget No. RSS-214 Heat Stress Monitor), or equivalent.

Initial Work Period Determination

The length of the initial work period will be determined by using one of the tables below:

These tables assume protective clothing must be worn, especially Levels A, B and C, the suggested guidelines for ambient temperature and maximum wearing time per excursion are:

Maximum Suggested Wearing Times

Ambient Temperature (°F) [dry bulb]	Maximum Wearing Time per Excursion (Minutes)
Above 90	15
85 to 90	30
80 to 85	45
70 to 80	60
60 to 70	120
50 to 60	180

Permissible Heat Exposure Threshold Limit Values (Values are given in °F WBGT)

	Work Load		
Work-Rest Regimen	Light	Moderate	Heavy
Continuous Work	75.0	72.0	69.0
75% Work - 25% Rest, Each Hour	77.0	74.0	72.0
50% Work - 50% Rest, Each Hour	81.0	79.0	77.0
25% Work - 75% Rest, Each Hour	84.0*	82.0*	80.0*

* If WBGT values exceed these limits, special control measures must be implemented.

B.I.4 Worker Monitoring

One of the following procedures shall be followed when the work-place temperature (dry bulb) is 70°F or above.

1. Heart rate (HR) shall be measured by the pulse for 30 seconds as early as possible in the resting period. The HR at the beginning of the rest period should not exceed 100 beats/minute. If the HR is higher, the next work period should be shortened by 10 minutes (or 33 percent), while the length of rest period stays the same. If the pulse rate is 100 beats/minute at the beginning of the next rest period, the following work cycle should be shortened by 33 percent.

2. Body temperature should be measured orally with a clinical thermometer as early as possible in the resting period and before drinking any liquids. Oral temperature (OT) at the beginning of the rest period should not exceed 100°F. If it does, the next work period should be shortened by 10 minutes (or 33 percent), while the length of the rest period stays the same. However, if the OT exceeds 99.7°F at the beginning of the next rest period, the following work cycle should be further shortened by 33 percent. OT should be measured at the end of the rest period to make sure that it has dropped below 99°F. At no time shall work begin with OT above 99°F.

3. A third method of measuring the effectiveness of employees' rest-recovery regime is by monitoring the pulse recovery rate. The "Brouha guideline" is one such method:

   - During a three-minute period, count the pulse rate for the last 30 seconds of the first minute, the last 30 seconds of the second minute, and the last 30 seconds of the third minute.

   - Double the count.

   If the recovery pulse rate during the last 30 seconds of the first minute is at 110 beats/minute or less and the deceleration between the first, second, and third minutes is at least 10 beats/minute, the work-recovery regime is acceptable. If the employee's rate is above that specified, a longer rest period is required, accompanied by an increased intake of fluids.

ATTACHMENT B.II
COLD STRESS
STANDARD OPERATING PROCEDURES

When the human body is exposed to a cold environment, certain internal mechanisms come into play which tend to limit heat loss and increase heat production. The first mechanism reduces the amount of heat lost to the environment by constricting the blood vessels, especially in the extremities, resulting in a sharp drop in skin temperature. Chilling of the extremities places a severe strain on this mechanism, and if activity is restricted, the toes and fingers may approach freezing temperatures very rapidly. When blood vessel constriction is no longer adequate to maintain body heat balance, metabolic heat production is improved by voluntary movements and by the onset of shivering. It is possible to increase the metabolic rate five to seven times for short periods by shivering, but this increase cannot be maintained indefinitely. These two mechanisms reduce the blood flow through the skin and thus lower the temperature so that less heat is lost by conduction and radiation. Reduction of surface area by changes in posture, such as curling up the body, also assists in reducing heat loss.

Persons working outdoors in temperatures at or below freezing may experience frostbite. Extreme cold for a short time may cause severe injury to the surface of the body. Areas of the body that have a high surface area to volume ratio, such as fingers, toes, and ears, are the most susceptible.

Two factors influence the development of a cold injury; ambient temperature and the velocity of the wind. Wind chill is used to describe the chilling effect of moving air in combination with low temperature. For instance, 10°F with a wind of 15 mph is equivalent in chilling effect to still air at -18°F.

As a general rule, the greatest incremental increase in wind chill occurs when a wind of 5 mph increases to 10 mph. Additionally, water conducts heat 240 times faster than air. Thus, the body cools suddenly when chemical-protective equipment is removed if the clothing underneath is soaked with perspiration.

B.II.1 Frostbite

Local injury resulting from cold is included in the generic term frostbite. There are several degrees of damage. Frostbite of the extremities can be categorized into:

1. Frost nip or incident frostbite - the condition is characterized by sudden blanching or whitening of skin.

2. Superficial frostbite - skin has a waxy or white appearance and is firm to the touch, but tissue beneath is resilient.

3. Deep frostbite - tissues are cold, pale and solid; extremely serious injury.

B.II.2 Hypothermia

Authorities agree that there are degrees of hypothermia which are characterized as "moderate" and "severe". A victim of moderate hypothermia exhibiting the first seven signs listed below is still conscious but often confused. Severe hypothermia is determined by extreme skin coldness, loss of consciousness, faint pulse, and shallow, infrequent, or apparently absent respiration. Death is the ultimate result.

Practically, the onset of severe shivering signals danger to personnel. Exposure to cold shall be immediately terminated for any severely shivering worker.

Signs of Hypothermia

The following symptoms are signs of hypothermia:

1. Severe shivering
2. Abnormal behavior
3. Slowing
4. Stumbling

5. Weakness
6. Repeated falling
7. Inability to walk
8. Collapse
9. Stupor
10. Unconsciousness

B.II.3 Emergency Action

Emergency action should consist of the following:

1. Remove the victim from the hypothermia/frostbite-producing environment.

2. Seek expert medical help immediately.

3. Reduce handling to a minimum. Do not rub or massage the victim.

4. Prevent further body heat loss by covering the victim lightly with blankets. Plastic may be used for further insulation. Do not cover the victim's face.

5. If the victim is still conscious, administer hot drinks; encourage activity, such as walking while wrapped in a blanket; and do not administer any form of sedative, tranquilizer, alcohol or analgesic (pain reliever), because these may assist in further heat loss and convert moderate hypothermia into a severe case.

B.II.4 Workplace Monitoring

Workplace monitoring is required as follows:

1. A thermometer accurate to 1°F should be assigned at any workplace where the environmental temperature is known or expected to be below 60°F to enable overall compliance with the requirements of this policy.

2. Whenever the air temperature at a workplace falls to 30°F or below, the dry-bulb temperature and wind speed should be measured and recorded at least every four hours.

3. The Equivalent Chill Temperature (ECT) should be obtained from the table in Attachment A in all cases where air movement measurements are required, and should be recorded with the other data in the site log, together with a record of the length of time spent working and resting.

B.II.5 Work-Warming Regimen

If work is performed continuously in the cold at an ECT of 20°F or below, heated warming shelters should be made available for use by employees during warmup breaks.

When entering the heated shelter (Contamination Reduction facility), the outer layer of clothing should be removed and the remainder of the clothing loosened to permit sweat evaporation. A change of dry work clothing should be provided as necessary to prevent workers from returning to their work with wet clothing. Dehydration, or the loss of body fluids, occurs insidiously and without warning in the cold environment and may increase the susceptibility of the worker to cold injury due to a significant change in blood flow to the extremities. Warm sweet drinks and soups should be provided at the work site to provide caloric intake and fluid volume. <u>The intake of coffee should not be permitted because of a diuretic and circulatory effect.</u>

For work practices at or below 10°F ECT, the following shall apply:

1. The worker should be under constant protective observation (buddy system or other direct supervision).

2. The work rate should not be so high as to cause sweating that will result in wet clothing; if heavy work must be done, all rest periods must be taken in heated shelters and the opportunity for changing into dry clothing should be provided.

3. Provision should be made for time to allow employees to become accustomed to the working conditions and required protective clothing.

4. The weight and bulkiness of clothing should be included in estimating the required work performance and weights to be lifted by the worker.

5. The work should be arranged in such a way that sitting still or standing still for long periods is minimized.

6. Unprotected metal chair seats must not be used. The worker should be protected from drafts to the greatest extent possible.

7. The workers should be instructed in cold weather procedures. The training program should include at a minimum instruction in:

   - Rewarming procedures and appropriate first aid treatment.
   - Proper clothing practices.
   - Proper eating and drinking requirements for cold stress.
   - Recognition of impending frostbite.
   - Recognition of signs and symptoms of impending hypothermia or excessive cooling of the body even when shivering does not occur.
   - Safe work practices.

B.II.6 Special Medical Considerations

Employees must be excluded from work in cold at 30°F or below if they are suffering from diseases or taking medication which interferes with normal body temperature regulation or reduce tolerance to work in cold environments. The Site Safety Officer shall document this information for each worker during site training. Workers who are routinely exposed to extreme cold stress conditions should be medically certified as suitable for such exposures.

Trauma sustained in freezing or subzero conditions requires special attention because an injured worker is predisposed to secondary cold injury. Special provisions must be made to prevent hypothermia and secondary freezing of damaged tissues in addition to providing for first aid treatment.

For exposed skin, continuous exposure will not be permitted when ECT of -25°F is anticipated.

At air temperatures of 36°F or less, any worker who becomes immersed in water or whose clothing becomes wet will be immediately be provided a change of clothing and be treated for hypothermia.

B.II.7 Personal Protective Equipment Requirements

Since prolonged exposure to cold air (or to immersion in cold water) at temperatures well above freezing can lead to dangerous hypothermia, whole body protection must be provided as follows:

1. Adequate insulating clothing to maintain core temperatures above 97°F must be provided to workers if work is performed in air temperatures below 40°F. Wind chill or the cooling power of the air is a critical factor. The higher the wind speed and the lower the temperature in the work area, the greater the insulation value of the protective clothing required. An equivalent chill temperature chart relating the actual dry bulb air temperature and the wind velocity is presented in Attachment A. The equivalent chill temperature must be used when estimating

the combined cooling effect of wind and low air temperatures on exposed skin or when determining clothing insulation requirements to maintain the deep body core temperature.

2. Older workers or workers with circulatory problems require special precautionary protection against cold injury. The use of extra insulating clothing and/or a reduction in the duration of the exposure period are among the special precautions which should be considered. The precautionary actions to be taken will depend upon the physical condition of the worker and should be determined with the advice of a physician with knowledge of the cold stress factors and the medical condition of the worker.

3. Special protection of the hands is required to maintain manual dexterity as follows:

   - If fine work is to be performed with bare hands for more than 10-20 minutes in an environment below 60°F, special provisions must be established for keeping the worker's hands warm. For this purpose, warm air jets, radiant heaters (fuel burner or electric radiator), or contact warm plates may be used. Metal handles of tools and control bars should be covered by thermal insulating material at temperatures below 30°F.

   - If the air temperature falls below 60°F for sedentary (none moving), 40°F for light, or 20°F for moderate work and fine manual dexterity is not required, then gloves should be used by the workers.

4. To prevent contact frostbite, the workers must wear anti-contact gloves and follow the provisions shown below:

- When cold surfaces below 20°F are within reach, a warning should be given to each worker by his/her supervisor to prevent accidental contact by bare skin.

- If the air temperature is 0°F or less, the hands should be protected by mittens. Machine controls and tools for use in cold conditions should be designed so that they can be handled without removing the mittens.

5. Provisions for additional total body protection is required if work is performed in an environment at or below 40°F. The workers should wear cold protective clothing appropriate for the level of cold and physical activity:

   - If the air velocity at the job site is increased by wind, draft, or artificial ventilating equipment, the cooling effect of the wind should be reduced by shielding the work area or by wearing an easily removable outer windbreak garment.

   - If only light work is involved and if the clothing on the workers may become wet on the job site, the outer layer of the clothing in use should be of a type impermeable to water. The outer garments must include provisions for easy ventilation in order to prevent wetting of inner layers by sweat. If work is done at normal temperatures or in a hot environment before entering the cold area, employees should make sure that their clothing is not wet because of sweating. If clothing is wet, employees should change into dry clothes before entering the cold area. The workers should change socks and any removable felt insoles at regular daily intervals or use vapor barrier boots.

   - If extremities, ears, toes, and nose cannot be protected sufficiently to prevent sensation of excessive cold or frostbite by use of conventional handwear, footwear, and face masks, auxiliary heated versions of these protective items should be provided.

- If the available clothing does not give adequate protection to prevent hypothermia or frostbite, work should be modified or suspended until adequate clothing is made available or until weather conditions improve.

APPENDIX C

QUALITY ASSURANCE PROJECT PLAN

INITIAL REMEDIAL INVESTIGATION
BIG RIVER MINE TAILINGS SITES
ST. FRANCOIS COUNTY, MISSOURI

DRAFT
APRIL 1995

CONTENTS

TABLES

FIGURES

C.1 PROJECT DESCRIPTION

This Quality Assurance Project Plan (QAPP) describes the policy, organization, functional activities, and quality assurance (QA) and quality control (QC) protocols necessary to achieve the data quality objectives (DQOs) of the BRMTS RI (see Section C.5.5 of the RI). The purpose of this QAPP is to ensure that the procedures used in the investigation will not detract from the quality of results, and that the results follow an approved plan and are properly documented.

This QAPP was prepared, in accordance with U.S. Environmental Protection Agency (U.S. EPA) guidance, for the data collection activities to be performed during the implementation of the RI at the BRMTS in Missouri. The RI activities to be conducted are described in Section C.5.5 of the RI and will be implemented by Fluor Daniel, Inc. on behalf of The Doe Run Company. Additional components of the field sampling which will be used for the RI will be completed by the Missouri Department of Health (MDOH) during the summer of 1995. The anticipated COPCs are lead, cadmium, and zinc.

Previous investigations indicate the presence of metals in the waste piles. A description of the site history, location, and previous investigations are presented in Sections 1 through 3 of the RI). The Field Sampling Plan (FSP) describes the RI procedures required to collect environmental samples. Samples collected during the RI activities will be analyzed at the laboratory. Specific analytical testing methods are described in Section C.7. Field activities are anticipated to begin in early summer 1995.

C.2 PROJECT ORGANIZATION AND RESPONSIBILITY

Fluor Daniel will be responsible for the performance and supervision of field activities. This includes supervision of sample collection, chain-of-custody records, and field analysis and testing activities.

Key personnel for the BRMTS site include the Project Manager, QA/QC Officer, Site Health and Safety Manager, and Field Operations Leader (see Figure C-2-1). The principal responsibilities for these positions are as follows:

The **Project Manager** is the overall manager of administrative activities and the principal point of contact for administration and coordination with the Doe Run Resources Company. The Project Manager is also responsible for coordinating, scheduling, and budgeting all project activities and is the principal point of contact on all technical issues.

The **Field Operations Leader** is responsible for managing the sampling, testing, and all intrusive activities associated with the site investigation. The Field Operations Leader will coordinate the site field work activities and interface with all personnel and subcontractors to ensure that all work is conducted in accordance with the approved work plans. He will be responsible for implementing the QA/QC program, and reviewing field data forms and procedures for accuracy. He will report weekly, at a minimum, to the Project Manager on the progress of work and any significant issues that may develop. He has the authority to make the technical decisions that are described in this Work Plan as being finalized in the field. For this project, the Field Operations Leader will also hold the position of Health and Safety Officer. Some of his responsibilities may be delegated to field team leaders.

The **QA/QC Officer** is responsible for assessing the implementation of the QAPP in support of the project. The QA/QC Officer is responsible for assuring the QA/QC program is implemented, including preparing and submitting QA/QC reports to management, and ensuring appropriate corrective actions are implemented, and scheduling and performing appropriate QA verification activities to ensure compliance with required procedures.

The **Site Health and Safety Manager** is responsible for monitoring field safety procedures and field activities, including well-drilling and testing. He or his representative will be present whenever work is in progress, coordinate the safety of all site work activities, interface with all subcontractors to ensure compliance with the Site Health and Safety Plan (HSP), and ensure that all work is safely conducted in accordance with the RI Work Plan and the HSP. Section III of this Work Plan contains the HSP. The Site Health and Safety Manager will assess the adequacy of the HSP during the course of the project and request modifications when warranted. The manager has the authority to temporarily suspend field activities if personnel are endangered and to recommend suspension of an individual from field activities for infractions of the HSP. He has a direct line of communication with the Fluor Daniel Regional Health and Safety Manager.

Work Plan Modifications

Modifications to the Work Plan during the course of the investigation at the BRMTS site may include changes to the scope of the project or minor changes to field or analytical procedures to ensure successful collection and analyses of environmental samples. Changes to scope can be made only by the Project Manager.

Minor revisions may be initiated by the Field Operations Leader with the approval of the Project Manager, QA/QC Officer, and Site Health and Safety Manager. Revisions will be processed using the Field Change Request form shown in Figure C-2-1. The Field Change Request forms will be numbered sequentially for each request; a copy will be maintained in the field while the original will be placed in the project file. The initiator of the form will fill in the description, reason for change, and recommended disposition; the form will then be submitted to the Field Operations Leader.

FIGURE C-2-1
FIELD CHANGE REQUEST FORM

Project Name:____________________ Date:____________
Project Location:____________________
Project No. ____________________ Field Change Request No. ______

To:__________________________(Field Operations Leader)

Proposed Change to:

Description:

Reason for Change:

Recommended Disposition:

Initiated by:____________________ Date:__________
Field Operations Leader:____________________ Date:__________

Approval:
Project Manager ____________________ Date:__________
QA/QC Officer ____________________ Date:__________
Site Health & Safety Coordinator ____________________ Date:__________

C.3 QUALITY ASSURANCE OBJECTIVES

The QA objectives have been designated to comply with requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 and the Superfund Amendments and Reauthorization Act (SARA) of 1986, as well as other potentially applicable laws and regulations.

The general QA objective is to ensure that data collected are of acceptable quality and are representative of site conditions. Environmental data collection efforts will adhere to the QA/QC procedures developed by the U.S. EPA for the collection, preservation, and analysis of environmental samples. The laboratory analytical efforts will adhere to that laboratory's QA/QC policy. The analytical data collected will conform to either Analytical Level III or IV as defined in the U.S. EPA guidance document DQOs (U.S. EPA 1987a). The U.S. EPA has established the following primary DQOs for environmental studies: precision, accuracy, representativeness, completeness, and comparability.

C.3.1 Precision and Accuracy

Precision is a quantitative measure of variability, that is, an estimate of agreement among individual measurements of the same physical and chemical property, under prescribed similar conditions. Analytical precision for a single analyte is expressed as percentage of the difference between results of duplicate samples for the analyte. Precision demonstrates the reproducibility of the data under a given set of conditions.

Accuracy is the degree of agreement between a measurement and the "true" or expected value. Sources of error include the sampling process, field contamination, preservation, handling, sample matrix, sample preparation, and analysis techniques. Sampling accuracy may be assessed by evaluating the results of field/trip blanks, and analytical accuracy may be assessed through the use of known and unknown QC samples and matrix spikes.

Precision and accuracy are determined, in part, by analyzing data from QA/QC samples. Analytical laboratory QA/QC samples for organic and inorganic analyses include calibration blanks, preparation (reagent) blanks, analytical laboratory duplicates, control samples, calibration standards, matrix spikes, and surrogate spikes.

The precision and accuracy of the chemical data will be calculated by the laboratory and confirmed by the laboratory's QA Manager at the conclusion of each phase of sampling and analyses. The results of precision and accuracy calculations from duplicate and spiked sample analyses will be presented in the laboratory sample result reports and included in the final report.

To ensure that an adequate number of QC samples are analyzed to sufficiently evaluate the quality of data collected, a minimum number of matrix spikes; field, trip, and laboratory blanks; and duplicates will be analyzed. The number of each of these QC samples that will be collected and analyzed is discussed in Section C.8. Procedures for assessing precision, accuracy, and completeness are presented in Section C.12.

C.3.2 Completeness

Completeness is the measure of the amount of valid data obtained compared to the amount that was expected to be obtained under optimum conditions. The database will be routinely assessed on the basis of expected versus actual data and will be developed to a point at which it is capable of supporting statistical analyses for interpretational purposes.

C.3.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Data representativeness is a function of sampling strategy; therefore, the sampling scheme should be designed to maximize representativeness. The collection of a systematic, random sample within the sampling area of concern can ensure good geographical coverage and minimize bias.

C.3.4 Comparability

Comparability is a qualitative measure of the confidence with which one data set can be compared with another. Sample data will be comparable to other measurement data for similar samples and sample conditions. Data will be reported in units consistent with both federal and state regulations, methods, and guidelines. Consistent, standardized sampling and analytical procedures will be applied throughout the RI program to ensure that differences in the analytical results do not result from variations in operational procedures. Any deviation from the standard will be noted, and data will be qualified for comparative purposes.

C.4 SAMPLE HANDLING PROCEDURES

The sample locations and the analyses selected for each sample were determined based upon the site information reviewed from previous investigations presented in Appendix B of this RI. The types of samples, sample locations, number of samples, and analyses to be performed are discussed in Section C.5.5 of the RI which presents the Field Sampling Plan (FSP). Sampling equipment and procedures are described in detail in the FSP.

C.4.1 Sample Containers and Preservatives

All samples collected for chemical analysis will be collected in the sample containers listed in Table C-4-1. Samples will be preserved in the field as indicated and as appropriate for the analyses to be performed. They will be analyzed within U.S. EPA holding times established for each analyses. Sample containers will not be rinsed prior to sampling so as to not lose any preservative, and to avoid any introduction of contaminants into the sample container.

C.4.2 Sample Identification

The method of identification of a sample depends on the type of measurement or analysis performed. On-site measurements will be recorded on field data forms with identifying information (i.e., project name, sample numbers, sample location, date, time, samplers), field observations, and remarks. Examples of on-site measurements for this project include pH and temperature. The field data forms shall be signed and dated by the authors and will be maintained as project records by the Field Operations Leader.

A sample identification number will be assigned to each sample to distinguish an individual sample from all other samples. This identification number will be used on all documentation relating to collection, handling, analysis, and reporting of the analytical results of each individual sample. Since a sample is normally analyzed for a number of different chemical constituents or parameters that require different sample containers and preservation techniques, the same sample identification number will be assigned to each portion of the original sample split among individual sample containers. Chapter 5.5.2.4 of the FSP provides more detail on sample identification.

Sampling at the BRMTS will consist of mine tailings. Sample labels provided by the laboratory will be affixed to each individual sample collected. The sample label on all samples collected during the site investigation will contain the following information:

- Project name and location
- Project number
- Sample location
- Sample identification number
- Date and time of collection
- Name or initials of sampler
- Analyses to be performed

C.4.3 Decontamination Procedures

All materials and equipment that come into contact with potentially contaminated soil, drilling fluid, or water will be decontaminated prior to and after each use. Decontamination will consist of steam cleaning, or a nonphosphate detergent scrub, followed by fresh water and distilled water rinses. After materials and equipment are decontaminated, they will be stored on clean plastic sheeting. A detailed discussion of the decontamination procedures is presented in Chapter 5.5.2.6 of the FSP.

C.5 SAMPLE CUSTODY

To establish the necessary documentation required to trace sample possession from the time of collection to the time of analysis, a Chain-of-Custody form will be completed and will accompany every sample through its transportation to the designated analytical laboratory. Sample custody procedures are designed in accordance with U.S. EPA Region VII SOP No. 2130.2A.

Chain-of-Custody forms will be supplied by the laboratory. The following information will be completed on the Chain-of-Custody form:

- Project number
- Total samples shipped
- Date samples are relinquished
- Signature of sample collector
- Sample identification
- Date/time samples collected
- Sample type
- Container type
- Sample preservation
- Analyses requested and analytical level
- Signature of person(s) involved in the chain of possession

C.5.1 Sample Packaging and Shipping

Each sample container will be sealed with a custody seal provided by the laboratory by wrapping the seal around the end of each container. All custody seals will be signed and dated by the sample collector. Glass sample containers will be wrapped with plastic shipping material to prevent breakage, then placed in plastic sealable bags. Samples will be packaged into shipping containers supplied by the Region VII Laboratory. Sample containers will be placed in a shipping container that contains ice triple-bagged in sealable plastic or Blue Ice, and absorbent packing for liquids or foam packing for solids. The completed Chain-of-Custody form will be placed inside the shipping container, unless otherwise noted. The container will be secured with strapping tape to prevent opening during shipment. The shipping container will be marked with the proper shipping name and hazard class. Two strips of custody tape will be placed on each shipping container, with at least one strip at the front and one at the back, located in a manner that would indicate tampering, if any had occurred.

C.5.2 Field Logs

Daily field logs will be maintained on-site during field activities by the Field Operations Leader to provide daily records of significant events, observations, and measurements during field operations. The purpose of field logs is to provide a record of events during investigation activities. In the event that an issue is raised, for example a sampling point, field records can be referred to for conditions of sampling location, on-site field measurements, etc.

C.5.3 Laboratory Files

Laboratory files will be maintained for each project in accordance with laboratory procedures. The file will contain all data and reports including raw data calculation sheets, chromatograms, and mass spectrums in both computer tape and hard copy form. All written and computerized records of laboratory handling and analysis will also be maintained as part of the permanent file. The files will be made available to the QA Supervisor, Laboratory Project Manager, and RI Project Manager upon request for review.

C.6 CALIBRATION PROCEDURES

Calibration is the process of adjusting an instrument response to match the concentration of a known reference standard. These procedures ensure the operator that the instrument is operating properly and will generate reliable data.

Procedures described in this chapter pertain to the calibration of equipment and instrumentation in the field and in the laboratory. The procedures specify calibration frequency and standards. All calibrations for field and laboratory equipment will be recorded in appropriate field notebooks. Equipment log books will be used to record events of maintenance and repairs.

C.6.1 Laboratory Instrument Calibration

The laboratory instruments used during the analysis of samples will be calibrated according to and at the frequency indicated by the specific analytical methods used. These analytical methods are discussed in Section C.7.2 of this QAPP. All instruments will be calibrated through the use of standard solutions of known concentrations. Standards will be prepared from certified reference solutions obtained from the U.S. EPA Repository or approved chemical vendors. As stated above, the instruments will be calculated at a frequency defined by the specific analytical methods used, but the calibration will be continuously verified by analysis of calibration standards or laboratory control samples at regular intervals. Calibration will be performed at specified time intervals or when continuous calibration verification procedures indicate the need. The instrument user is responsible for documenting calibration procedures. Laboratory calibration and calibration verification acceptance criteria are listed in Table C-6-1.

TABLE C-6-1
ACCEPTANCE CRITERIA FOR INSTRUMENT CALIBRATION

Analysis	Initial Calibration Linearity	Verification
Metals	Correlation coefficient of: > 0.9995 > 0.9990:AA > 0.995:Cold Vapor	+/- 10 % of true value

C.7 ANALYTICAL PROCEDURES

Analytical procedures performed for the BRMTS RI will include laboratory analyses.

C.7.1 Laboratory Analyses

Laboratory analytical methods to be used on samples collected as part of the RI are summarized in Table C-7-1. Actual detection limits obtained during analysis will be reported for each parameter in each sample. Highly contaminated samples or samples containing interfering substances may result in elevated detection limits.

- U.S. EPA Methods 200/6000 Series for metals in water/soil (including U.S. EPA Region VII SOP No. 3110.1B and 3110.3B)

Methods for metals are based on U.S. EPA's *Test Methods for Evaluating Solid Wastes* (SW-846, 3rd edition).

The analytical data will conform to Level IV analytical support levels.

CLP RAS provides analyses of all types of media for hazardous substance list organic compounds and priority pollutant inorganic compounds. Level IV analyses are used for confirmation of lower level data, risk assessment, and to obtain highly documented data. The CLP RAS is specific concerning the documentation that is supplied with every data package. The bias and precision of CLP analytical procedures can be assessed by examining the performance of the laboratory in analyzing matrix spikes and results of quarterly laboratory performance evaluation samples.

All analyses will be performed in accordance with the analytical laboratory's QA/QC plan as well as in accordance with appropriate analytical methods.

TABLE C-7-1
ANALYTICAL METHODS

Parameter	U.S. EPA Method (water/soil)	Detective Limit	Analytical Method
Cadmium	200.7/6010	4.0/0.5	ICP
Lead	200.9/6010	1.0/1.0	GF-AA
Zinc	200.7/6010	12/.05	ICP

C.8 INTERNAL QUALITY CONTROL CHECKS

Both laboratory and field QC checks will be employed to evaluate the performance of laboratory analytical procedures. QC checks will take the form of samples introduced into the analytical stream to enable evaluation of analytical accuracy and precision.

C.8.1 Analytical Quality Control

Analytical QC procedures are implemented to identify possible introduction of contaminants as a result of equipment contamination and/or analytical procedures and to assess the validity, accuracy, and precision of the analytical results. The QC checks in the laboratory protocol include the calibration of instruments and are specific to the analytical method of interest. QC checks include the following:

- Reagent blanks
- Matrix and surrogate spikes
- Method spikes
- Laboratory duplicates

Spike, duplicate, and blank analyses are completed by the laboratory to obtain information regarding the accuracy and precision of analytical methods and to identify any contaminants introduced to the sample during analytical procedures. Table C-8-1 presents a summary description of QC samples and their application. Laboratory duplicates are a second analytical run of a sample. Analysis of one duplicate sample for at least ten percent of the samples analyzed will be performed. The results are evaluated by calculating the relative percent difference (RPD) between two runs, and comparing the RPD to established acceptance criteria.

A reagent blank is an analytical run without the addition of a sample to the reagent base. Compounds detected in reagent blanks may indicate laboratory sources of contamination. Analysis of one blank sample for at least ten percent of the samples analyzed will be performed.

A matrix spike is a sample with a known concentration of certain species of interest added to identify matrix affects that may interfere with the detection of the added species. Analysis of one matrix spike sample for at least ten percent of the samples will be performed.

Surrogate spikes assess the recovery for key species (volatile, base/neutral, and acid compounds) for every sample analysis. Surrogate spike results are evaluated for acceptable recoveries by the laboratory, and are not transferred to the database for further evaluation. The percentage of the "spiked" species recovered indicate loss or gain of the species from the analytical equipment or procedures used.

Method spikes are also reported as percentage recovery. Method spikes are method blanks spiked with an analyte of interest. The same control check standard issued by the U.S. Environmental Protection Agency (U.S. EPA) is used throughout the project. The method spike is analyzed prior to the sample analyses. All compounds of interest must show adequate recovery before actual sample analyses occur. This ensures that the system performance is acceptable.

C.8.2 Sampling Quality Control

Collection and analyses of field equipment, trip blanks, and field replicates are intended as QC checks on representativeness of the samples collected, the precision of sample collection and handling procedures, and thoroughness of the field equipment decontamination procedures between sampling events. A sampling event is considered to be from the time the sampling personnel arrive at the site until these personnel leave for more than one day.

TABLE C-8-1
DESCRIPTIONS AND APPLICATIONS OF QUALITY CONTROL SAMPLES

Sample Type	Type of Analysis	Description	Application
Quality Control Check Sample	I, O	Standard; obtain from source other than calibration standard.	Indicates accuracy and consistency of calibration.
Detection Limit Quality Control Check	I	Standard at a constituent concentration 2 to 3 times the detection limit.	Indicates accuracy at lower end of linear dynamic range.
Calibration Blank	I, O	Reagent-grade water (zero constituent concentration).	Indicates instrument signal drift and sample contamination.
Preparation Blank	I, O	All reagents used during digestion step (ASTM Type II water).	Indicates sample contamination.
Equipment Blank	I, O	Reagent-grade water processed through a clean, nondedicated sampling device and analyzed as if it were real sample.	Indicates effectiveness of cleaning procedure.
Trip Blank	I, O	Reagent-grade water transported to sampling site in each of the types of sample collection containers used. The containers are then returned as routine water samples.	Indicates contamination caused by sample handling and analysis.
Internal Standard	O	Single-constituent standard.	Quantifies target constituent.
Surrogate Spike	O	Sample fortified with surrogate spiking constituent.	Indicates contamination caused by sample preparation analysis, or matrix.
Anal. Lab. Duplicate	I	Sample aliquot, split at the analytical laboratory.	Indicates analytical intralaboratory precision.
Matrix Spike	O	Sample plus known quantity of constituent.	Indicates sample matrix effect on analysis and on accuracy of measurement system.
Matrix Spike Duplicate	O	A second matrix spike sample.	Indicates intralaboratory precision.

Note:
I = Inorganic analysis
O = Organic analysis

Field blanks, equipment blanks, and trip blanks are prepared using ASTM Type II reagent-grade water and sample containers. All blanks will be handled and analyzed in the same manner as samples collected from the site. Sample numbers for the blanks collected shall be sequential with the samples collected.

One trip blank per every twenty field samples of water will be submitted to the laboratory. It will be transported in one of the coolers containing water samples on each day that samples will be shipped. The trip blanks will be analyzed for the same constituents for which samples are analyzed.

Trip blanks will be prepared at the laboratory by pouring ASTM Type II reagent-grade water into sample containers. Appropriate sample volumes for each type of organic and inorganic analyses will be prepared and shipped with the clean, unused sample containers, transported to the sampling site, and then shipped to the analytical laboratory for analysis along with the samples collected during the sampling event. The results of the trip blank analysis will be reported along with the associated environmental and QC samples. The trip blanks will remain unopened throughout the sampling event. Analysis of trip blanks is used to assess the contamination of sample containers during transport to and storage at the site and contamination of samples during shipment to the laboratory.

Equipment Blanks (rinsate samples) will be prepared for manual sampling equipment used to collect samples from all media. Analyses will be same as for the samples being collected with the sampling equipment. Equipment blanks will be collected during the sampling period by pouring ASTM Type II reagent-grade water into, through, or over a decontaminated piece of sampling equipment, and then dispensing it into prepared sample containers. Equipment blanks will be prepared using appropriate sample containers for each of the analyses requested in the samples collected. Results from equipment blanks are used to assess the efficiency of sampling equipment decontamination procedures used to prevent cross contamination of samples collected during successive sampling events. Rinsate samples will be collected at a rate of one sample per sample excursion. A sample excursion is considered a continuous series of sample activities (e.g., soil boring).

Duplicate Samples are divided from the same sample somewhere along the measurement process. After division, each sample is carried through the same process. Field duplicated samples provide information on homogeneity, handling, shipping, storage, preparation, and analysis. One out of every twenty investigative soil/sediment samples will be field duplicated. All analyses for the original sample will be repeated for the duplicate.

C.8.3 Field Quality Control

A field QC program will be implemented daily to ensure that all field data forms have been completed correctly and accurately and that documentation of procedures, methods, techniques, ambient conditions, and any deviations from procedure have been entered into the field notebook. The following items will be reviewed by the Field Operations Leader at the conclusion of each day's activities:

- All field data forms are completely and correctly prepared.
- All samples have been collected, accounted for, and properly handled.
- All sample containers have been labeled as required.
- All sample documentation (chain-of-custody, custody seals) has been clearly, accurately, and specifically completed.
- All analytical request forms are accurately and specifically completed.
- Sample packaging and shipment was conducted according to specifications.
- Any suspect field or sampling data that may have not been clearly recorded is accurately and specifically documented in the field notebooks.
- The field notebook contains all requisite entries.

- Any photographs taken are documented in the field notebook.

- Decontamination procedures are verified completed.

C.9 DATA HANDLING, VALIDATION, AND REPORTING

To provide legally defensible data, it is necessary that all field and technical measurement data have an appropriate degree of completeness, accuracy, and reliability, along with assurance that samples and field measurements collected are representative of actual field conditions. Data collected during the sampling activities for the RI will be appropriately identified and validated and included in the final RI report. Where test data have been reduced, the method of reduction will be described in the text of such reports. All data received from the analytical laboratory and field analyses will be reviewed, checked, and cross-checked by the QA/QC Officer prior to its release to verify that it reasonably reflects known or expected conditions.

C.9.1 Data Quality Assurance

To ensure the precision, accuracy, completeness, representativity, and comparability of field and analytical data, the following protocols will be used:

- U.S. EPA-approved sampling procedures, as specified in the FSP and this QAPP, will be used at all times.

- Laboratory analysis of all environmental samples will be performed by a laboratory that follows U.S. EPA CLP protocol.

- Objectives for analytical work in terms of precision, accuracy, and completeness will be in accordance with the intent of U.S. Environmental Protection Agency (U.S. EPA) CLP or equivalent specifications.

Data collected during the site investigation will be communicated accurately and managed properly. Data processing and storage are essential to preserve both the field and analytical measurement results, as well as inputs for data assessment and reporting. The information will be carefully documented to support future legal or regulatory actions that may manifest. These actions may not occur for years after the data have been collected, validated, and compiled. Therefore, it is most important that records be sufficiently detailed to provide a complete and accurate history of data collection, validation, and compilation.

C.9.2 Documentation of Field and Technical Data

Proper identification and documentation of all samples is important in the collection of data for environmentally related conditions and situations. The data collected are often used to support regulatory and management decisions, risk assessments, litigation proceedings, etc. Therefore, it is critical that the appropriate means for tracking all samples back to their origination is established.

The data collected will be divided into field data and technical documentation. Field documentation will contain data from all field measurements collected as specified in the FSP and this QAPP. Technical documentation will consist of combined field and analytical data and will serve to guide the site investigation and provide a historical record on the chemical quality of the site. Technical data will include all field and analytical data, plus the results of the field and laboratory QC samples, and will be incorporated into the final RI report.

C.9.2.1 Documentation of Field Data

Sample tracking will be accomplished in the field by assigning each sample a unique sample label as it is collected. The sample identifier will be traceable back to the day, time, site, and depth (where appropriate) of collection. The sample identifier will be noted on a sample label and Chain-of-Custody form as well as recorded in the field notebook. A master log of the identifiers used will be maintained by the Field Operations Leader.

Most methods of analysis for samples must be accomplished within a specific amount of time after the collection of the sample. Where required, these time frames ("holding times") are given in the analytical method (see Section C.4.1 of this QAPP). Careful tracking of the analytical status of samples is required to ensure that these holding times are met.

C.9.2.2 Documentation of Technical Data

All bench chemists will document sample preparation activities in a bound laboratory notebook, which serves as the primary record for subsequent data reduction. The data for GC/MS and GC analyses are generated by stand-alone computers and integrators, respectively. The data for atomic absorption analysis are collected using the instrument's recorder to measure absorbance readings and strip chart to record absorbance expressed in peak height units. Results of each analysis will be transcribed manually onto analytical results forms specific to the particular analysis. All data are checked for accuracy and precision at the bench and instrument operator/analyst level, the laboratory manager's level, and the laboratory QA/QC Officer's level. The laboratory QA/QC Officer's review will consist of comparing spike recovery and/or RPD to control limits established for the parameter analyzed. Concentration of the analytes found in the analysis will be expressed according to the required units, depending on the sample matrix.

9.3 Data Validation

A sampling and analyses program produces a variety of chemical and physical data. The evaluation of these data provide fundamental evidence necessary to assess whether the site is contaminating the environmental setting and affecting biologic receptors, and to evaluate the temporal, spatial, lateral, and vertical extent of contaminant migration along transport pathways.

The analytical laboratory must report data correctly, either via electronic transmittal or in hard-copy format, to ensure the accuracy of the analytical methods and resultant data. Every effort should be made to minimize data transcription and reporting errors because statistical analyses may not always identify these errors.

C.9.3.1 Field and Technical Data Validation

Validation of field data will be performed on two different levels. First, all field data will be validated at the time of collection by following the QC checks as outlined in Section C.8 of this QAPP. Second, field data documentation will be validated to identify discrepancies or unclear entries. Field data documentation will be validated against the following criteria as specified in the FSP and this QAPP:

- Sample location and adherence to the FSP
- Sample collection protocol
- Sample volume
- Sample preservation
- All blanks collected and submitted with each respective sample set
- All duplicates collected and submitted with each respective sample set
- Chain-of-Custody protocol
- Shipment of samples
- Decontamination procedures

C.9.3.2 Laboratory Data Validation

Analytical data documentation will be validated against the following criteria as specified in this QAPP:

- Chain-of-custody protocols
- Sample condition upon arrival at the analytical laboratory
- Analysis data versus applicable sample holding times
- Frequency of QA/QC analysis
- Laboratory blank contamination
- Laboratory precision (relative percent difference versus control limits)
- Laboratory accuracy (percent recovery versus control limits)

The review and reporting is the final step of the QC procedures for the analytical laboratory. If data fall within the ranges specified for precision, accuracy, and method blanks (see Section C.12 of this QAPP), and all calculations and instrument calibration curve response data have been verified, then the data are accepted as valid. When QC data are not within the specified window, corrective actions must be taken after identifying the source of the problem. The corrective action includes evaluation of the data for method blanks, spikes, and duplicates, re-check of all accuracy calculations, and review of all bench sheet and instrument calibration data. If QC data are out of control, then it will be necessary to re-run the analysis. Any samples associated with out-of-control QC data will be re-analyzed.

Chemical interferences will be evaluated if calculations are correct and instrument data are acceptable. If chemical interferences are present and judged to be adversely affecting the method, then a revision of that method of selection or a new method is required. If no chemical interferences are present, and all instrument operational parameters and QC data are acceptable, then the analytical data are judged acceptable.

All field measurement data will be originally recorded in either the field notebook or field measurement logs. Lithologic descriptions will be recorded on boring logs. Following sampling activities, all field measurement notebooks and logs will be compiled and bound as an appendix to the final RI report. Any data that will be included in the final report will be tabulated and cross- checked against the original data sheets by at least one person independent of the person tabulating the data.

C.9.4 Laboratory Data Reduction and Reporting

Raw data and its reduction to final results will be reviewed by the laboratory section supervisor periodically. The frequency and completeness of the review will be individually determined but will not be less than 10 percent of all data every two weeks.

Results of laboratory analyses of samples will be reported in an appendix to the project report and grouped with the appropriate QC samples. If one of these check samples corresponds to more than one group of samples, it will be reported with each group, for ease of data evaluation.

All QC data pertinent to the samples taken as part of the confirmation investigation will be reported and cross-referenced to each applicable sample, including method blanks.

For those samples in which confirmation of identification and quantification is required by second-column chromatography, the confirmation data will be reported side-by-side with the first column data, separate from the environmental data. This is in addition to reporting the first column chromatographic analysis results with the other environmental data.

Laboratory QA/QC data will be reported separately from the environmental data but grouped by analysis method. Data necessary for calculation of percent recoveries will be presented along with the analytical results. The section containing QA/QC data also will include upper and lower control limits for percent recovery and RPD for all analyses.

Complete evaluation of the analytical data requires that the data be reported completely and correctly. The following information is required for complete evaluation of the analytical data and will be reported separately:

- Dates that samples were collected in the field
- Dates that samples were received in the laboratory
- Extraction and analysis dates for all samples
- Applicable holding times for each analysis
- Analysis dates for QC samples and designation of their associated batch

Final results will be reported daily on worksheets and entered into the computerized database. Result verification sheets will be returned to the analysts for manual verification of entered results. Data management personnel will then verify the hard copy results against the results entered into the database.

Management Review of Data

Each project performed at the laboratory will be assigned to a project manager when the first samples are received. The Laboratory Project Manager is responsible for tracking the progress of the samples while they are in-house and for ensuring timely analysis.

When the data are complete, the manager will review the final report against the following criteria:

- Reasonableness of data (e.g., whether results reported on various analyses on the same sample make sense when compared to each other). This includes general mineral balances, volatile organics measured by different methods, pH and electrical conductivity, and other analytical interrelationships. The manager will also compare data on samples within the same accession number, and if descriptive information about the samples is available, may conclude that the results are reasonable in comparison to each other.

- Accuracy in transcription of names, dates, sample numbers, results, and consistency in labeling throughout the report.

- Acceptability of QA/QC data: The laboratory's computerized data management system has the built-in feature of not allowing sample results to be verified without corresponding QC data. The Laboratory Project Manager ensures that the QC data are within acceptance limits and that all QC data are included in the final report.

All data reports, including raw data calculation sheets, chromatograms, and mass spectrums, are archived on computer tape and in written documents for storage within a secured building. These documents will be stored for no less than seven years and made available to the Project Manager upon request for review. The data of the sample extraction and analysis and the dilution factor for each sample (if applicable) will be included in the laboratory analytical reports. The report requires the signature of both the Laboratory Manager and the Laboratory Project Manager before it is released.

C.10 PERFORMANCE AND SYSTEM AUDITS

System audits and performance evaluation audits are essential in every QA program. These audits are used to evaluate compliance with the QAPP and to assess the overall quality of data collected during the measurement process. Moreover, audits are useful in evaluating sample collection, sample analysis, and data handling procedures. The objective of these audits is to minimize the collection of invalid data by detecting potential problems before the sampling and analytical measurements have been completed.

The Field Operations Leader will conduct at least one unscheduled field audit during the course of the investigation and sampling program. The audit will review sampling methodology and sample chain-of-custody, as well as review all data reporting methods and data files. The Field Operations Leader is responsible for preparing a written audit plan, directing the preparation of audit checklists or guides, conducting the on-site audit, and preparing the audit report. Findings will be presented in clear, concise statements of fact that identify the problem. The QA/QC Officer will review this audit report and the supporting documentation.

Deficiencies will be written by the Field Operations Leader or the QA/QC Officer only when there is a clear violation of a specific QA requirement. Findings that require immediate corrective action will be reported immediately to the Project Manager and recorded on the audit record. The QA/QC Officer will be responsible for coordinating the responses to the audit report, developing a tentative plan and schedule of corrective actions, and scheduling follow-up audits, if necessary.

C.10.1 System Audits

A system audit is an in-depth evaluation of a sampling or measurement system. The objective is to assess and document data collection, data validation, analytical measurement processes, calibration procedures, sampling practices, data reporting, and QC activities. The QA/QC Officer will conduct this audit by reviewing field documents and log books from the field for accuracy and proper procedures. During the audit, the auditor will summarize all observations in an evaluation report and should bring all problems observed to the attention of the Field Operations Leader for corrective action.

C.10.1.1 Field Sampling

System audits for tailings sampling and the sampling and field analyses programs will be performed once. If additional phases of sampling and analysis are performed, additional system audits may be scheduled. System audits will be performed as early as possible to ensure that any developing problems are identified at the earliest time possible.

C.11 PREVENTIVE MAINTENANCE

C.11.1 Laboratory Equipment

The maintenance of laboratory equipment will be performed by the laboratory according to specific equipment calibration, operation, and maintenance procedures.

C.12 DATA ASSESSMENT PROCEDURES

C.12.1 Data Precision

Precision is a measure of the mutual agreement among individual measurements of the same parameter under prescribed, similar conditions. The closer the numerical values of the measurements approach each other, the more precise the measurement. This allows immediate comparison of the precision of different results under the same method.

C.12.1.1 Laboratory Data

Analytical precision will be determined through the use of matrix spikes and matrix duplicate spikes for the analytical work to be performed. The laboratory shall select samples at the frequency listed in Chapter 8.0 of this QAPP and split the sample into three aliquots. The first aliquot will be analyzed routinely for the analytes of interest, while the other two will be spiked with known quantities of the analytes of interest prior to analysis. The percent recoveries of the spiked amounts will be compared, and the RPD will be calculated and used as an indicator of the precision for the analyses performed.

Duplicate samples analyzed by the laboratory will assess the precision of the sample collection operations. Control limits for duplicate RPDs will be set at 0 to 20 percent to provide an initial guide. For any given concentration, the mean and standard deviation of the replicates will be calculated. Analytical data from each sample set will be pooled with previous sample sets to generate control and warning limits for the next set. Warning and control limits for soil and water samples will be set at +/- 2 standard deviations, and +/- 3 standard deviations, respectively.

C.12.2 Data Accuracy

Accuracy refers to the degree of difference between measured or calculated values and the "true" value. The closer the numerical value of the measurement comes to the true value, or actual concentration, the more accurate the measurement. Systematic errors affect accuracy. Accuracy is generally expressed as percent recovery.

C.12.2.1 Laboratory Data

Analytical accuracy shall be determined from the analytical results of matrix spike, matrix spike duplicates, and surrogate spikes. Analytical accuracy is expressed as the percent of recovery of an analyte that has been added to the field sample at a known concentration before analysis. Analytical accuracy is determined by dividing the total concentration found in the spiked sample by the total concentration added to the sample. Acceptable recovery limits for each analytical method are presented in Section C.8 of this QAPP.

C.12.3 Data Completeness

Completeness is expressed as the percentage of valid data obtained from a measurement system. For data to be considered valid, it must meet all of the acceptance criteria, including accuracy and precision.

C.12.3.1 Laboratory Data

Analytical completeness shall be expressed as the percentage of the amount of valid data obtained compared to the amount of data expected. Completeness will be calculated by subtracting the invalid data points from the total number of data points generated by the laboratory QC check samples, dividing the difference by the total and multiplying by 100.

All QC sample results will be evaluated against established U.S. EPA CLP criteria and historical laboratory control limits. Data points will be generated from preparation blank, matrix spike, and matrix spike duplicate samples for all analyses. Invalid data points are those parameters (percent recovery and RPDs values) which fall outside the required control limits, method blanks beyond the acceptance criteria (Section C.8), or any analysis conducted outside the specified sample holding times.

The DQOs for completeness, or the percentage of valid data supporting the analytical results, will be 95 percent. The minimum acceptable percentage will be 90 percent.

C.13 CORRECTIVE ACTIONS

C.13.1 Laboratory Corrective Actions

The need for corrective action in the laboratory comes from several sources: equipment malfunction, failure of internal QC checks, method blank contamination, failure of performance or system audits, and noncompliance with QA requirements. All laboratory corrective actions taken will be immediately reported to the Project Manager and appropriately documented in accordance with laboratory procedures.

Corrective action documentation will include the following information:

- Nature of the problem
- Date and time of discovery
- Analytical parameter affected

- Sample lot affected
- Date, time, and description of the resulting corrective action
- Signature of Laboratory QA Manager

C.14 QUALITY ASSURANCE REPORTS

Following completion of the BRMTS RI, a Quality Assurance Report will be prepared. The report will summarize the data collection activities as performed in relation to this QAPP. A summary will also be provided of the audits performed, their results, and any QA/QC problems identified. Should any QA/QC problems be encountered, the QA Report will describe the problem and subsequent corrective action performed.

C.15.0 REFERENCES

U.S. EPA, 1984, Guidelines Establishing Test Procedures for the Analysis of pollutants Under the Clean Water Act, 40 CFR Part 136.

U.S. EPA, 1986, Test Methods for Evaluating Solid Waste, SW-846, 3rd Edition.

U.S. EPA, March 1987a, Data Quality Objectives for Remedial Response Activities, Development Process, U.S. EPA/540/G-87/003.

U.S. EPA, December 1987b, A Compendium of Superfund Field Operations Methods,

U.S. EPA, October 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, U.S. EPA/540/G-89/004.